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A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Soil Moisture and Sugar Cane:

The interrelation of soil moisture and the cane plant, dealt with heretofore in this journal on the basis of reporting special phases of study, is here handled as a practical review of the subject as a whole. The paper is one that will be welcomed by plantation men who have come to feel the need of apt information on this general subject.

New Cane Varieties:

A list is presented of new varieties that are considered worthy of spreading so that observations can be made on their performance on larger areas.

P.O.J. 2878 in the Factory:

A detailed account is given of the experimental use of clarification aids in handling refractory juices of the celebrated Java variety.

Phosphate Fixation:

A laboratory study presents in definite terms the varying degrees in which phosphates are held by Hawaiian soils. As an item in soil classification the determination of the phosphate fixing capacity gives promise of finding a useful place.

Costs that Relate to Mill By-products:

What does it cost to apply press-cake and molasses to the field? Some answers to this question are supplied from the plantations.

Grade "A" Requirements:

Field experiments under conditions of fluming present special difficulties. The problems of bundle weighing and taring have received special consideration and the minimum requirements for a Grade "A" status of accuracy are here set forth for the benefit of those whom they may concern.

The Juice Sampling Error Due to Wet Field Trash:

The error that attaches to flume water dilution of the first expressed juice has been painstakingly explored and a correction has been suggested.

The Parshall Flume:

A refinement in setting the flume is presented and explained.

The Industry in Mauritius:

A description of sugar production in Mauritius is taken from a French journal.

Soil Terminology:

Not only the layman and the agriculturist but the specialist as well is apt to find this comprehensive explanatory list of soil terms a valuable aid to his understanding of a great range of terms that have found their way into the language of those who have occasion to speak and write of soils.

Soil Moisture and the Sugar Cane Plant

By H. A. Wadsworth

Introduction

This short discussion of the local work in the relation of the sugar cane plant to soil moisture makes no claims for originality. The general conceptions upon which our present ideas are based and the experimental evidence which indicates the application of these conceptions to local conditions have been discussed in technical meetings of many sorts and reported in detail in *The Hawaiian Planters' Record* and other journals. It is perhaps unfortunate that although most of these reports have dealt with certain particular phases of a large general subject, the integration of these piecemeal studies into the general plan of investigation has apparently been slighted. The purpose of the present paper is to rectify this fault. It is purposely kept free of experimental detail, results only being reported, together with some expression of the significance of these results and the credence with which they may be accepted. References to the original work throughout the discussion may serve as an index to the literature and to the unpublished material in the project files of the Experiment Station, H. S. P. A. This list of references is not exhaustive; however, most of those mentioned carry citations which may be used to increase their scope.

Soils and Soil-Moisture Relationships

Soil moisture is ordinarily expressed as a percentage of the soil's oven-dry weight. Thus, if a sample of field soil when wet weighs 125 grams and after being oven dried to constant weight at 110° C., weighs 100 grams, the moisture content is reported as 25 per cent. Simple as this conception may be, we do not know how these 25 grams of easily liberated water were held when the soil was in the field. The English workers (8) would have us believe that the moisture was held in thin films around small inert grains of soil similar to small marbles or shot. More recently it has been suggested (21) that all the water in the soil under field conditions and with free drainage is colloidally bound, little or none being held in films around the grains. Some soils are so rich in materials, which may be readily hydrated (10), that it would appear that some moisture might occur in loose chemical combination at high moisture contents and be lost during the process of drying. Many attempts have been made to classify soil moisture with only indifferent success (11).

Regardless of the form in which this moisture occurs, the distribution of water through the soil after irrigation or after a rainfall is readily understood. The following more or less categorical statements summarize the results of several years' intensive study of soil moisture distribution:

(a) When irrigation water is applied to a deep uniform soil it moves downward wetting each cubic inch of soil to a definite moisture content which is deter-

mined by the nature of the soil. Uniform distribution is attained within a few hours after the water disappears from the surface (16).

(b) Subsequent movement of this soil moisture under the so-called "capillary forces" or by temperature effects is at such a slow rate that any such movement is insignificant as far as plants are concerned (1).

(c) Losses of soil moisture by evaporation from the soil surface after irrigation are limited to losses from the surface layer (16).

(d) Except for this minor loss of soil moisture by surface evaporation, moisture is lost from a soil mainly through the action of plant roots. The rate at which soil moisture is depleted in any area is a measure of the concentration of feeding roots within that area (6).

It should not be understood that the definite moisture content suggested in the statement (a) above is the same for all soils. Soils differ widely in their water-holding capacities, as everyone knows, but when this capacity is known the depth to which a given quantity of irrigation water will penetrate can be easily determined. An expeditious method of securing a reliable measure of the water-holding capacity of any soil is the moisture equivalent procedure (3), (20).

The Relation of the Cane Plant to Soil Moisture

The interest of the plantation man does not cease with getting the water into the soil; what happens to it is of equal importance. As has been indicated above, not much of this moisture is lost by surface evaporation. It remained, however, for Briggs and Shantz (4) to express the relation between the phenomena of wilt and soil moisture contents. These workers in 1912 announced that all plants, regardless of their botanical nature, showed signs of wilt at the same moisture content when those plants were grown on the same soil. This moisture content they called the "permanent wilting percentage." As might be expected, such an announcement raised a storm of protest, most of it originating in the Desert Laboratory at Tucson, Arizona. Here the observers seemed to feel that symptoms of wilt were more closely associated with the evaporating power of the atmosphere than any soil characteristic (5). The debate has died away in the last few years and one is left with the impression that the participants during the argument were not talking about the same thing. Recent substantiation in California (18) of the major premises of Briggs and Shantz, and locally (7), (14), (22) emphasizes the point that the permanent wilting percentage of a soil is one of its most important characteristics. The method for determining it has already been described (22).

The local work mentioned above focused interest upon a characteristic of the cane plant which had apparently escaped notice in keeping with its importance. This was that visible symptoms of wilt were not apparent with sugar cane until long after this point had been reached. There is no rolling of the leaves as with corn, nor any evident loss of turgidity of leaves as with sunflowers, nor is there any evident change in leaf color; but elongation ceases at about the same moisture content that resulted in these characteristic signs of wilt with other species (14). The fact that growth in the sugar cane continues at a uniform rate until the soil moisture is reduced to the permanent wilting percentage, after which it makes no significant further growth until water is added to the soil, is of greatest importance.

This proposition when added to the four which have been previously given furnishes a valuable guide to plantation practice as well as to field and pot experimentation.

Such a sweeping conclusion could not be accepted upon the basis of the results secured from a score of trials with small containers, although these results were in perfect accord with parallel but not identical results elsewhere (17), (19). Consequently, an elaborate system of large containers was established by means of which the conclusions of the pots studies might be verified not only for small plants but throughout the entire crop history from planting to harvest.

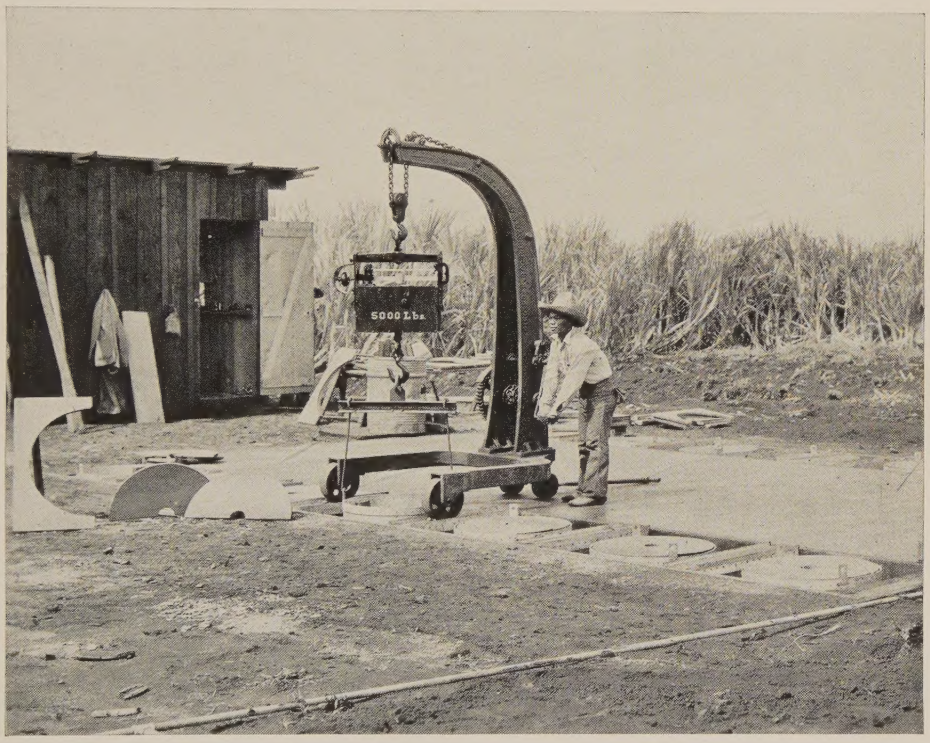

Fig. 1. This balance provided a means of measuring the daily uses of water by the plants in the tanks. Although of great capacity it was sensitive to about three pounds.

The physical equipment required for this work has been often described and the results reported in printed form and in the project file of the Experiment Station (13), (15). Briefly, the equipment consisted of fourteen large tanks, almost 6 feet high, and 28 inches in diameter. These tanks were uniformly filled with screened soil, of which the significant soil-moisture constants were known. When in place the tanks were set in long, deep trenches on either side of a concrete runway so that their tops were at the original ground level. A traveling crane on the concrete runway permitted the rapid and accurate weighing of the tanks, although each weighed more than a ton when ready for planting. In all cases the surface of the soil was protected from evaporation. Since the ever-increasing weight of the plant may be allowed for, it is evident that the gross weight of the tank is a measure of the average percentage of moisture in the tank, for water is

Fig. 2. Carefully grown plants were transplanted to the screened soil in the tanks. One of the evaporation screens is immediately behind the tank.

the only measurable variable in the system. In addition to a daily weighing of the tanks, the operations included the frequent measuring of length growth, total length being reported as the sum of lengths for all the stalks in the stool. Three views of the equipment used are given in Figs. 1, 2 and 3.

Some of the tanks were irrigated frequently so that a deficiency of water might never be experienced. Others were irrigated at longer intervals, while some were allowed to go so long between waterings that distinct signs of distress through water shortage were apparent. The results of these observations added one more general principle to those that have already been given:

> Sugar cane grows normally over a wide range of soil moisture contents. Apparently growth is not retarded by deficient soil moisture until the wilting percentage for that soil is reached.

It should be said that this finding is in perfect accord with similar work elsewhere, although length growth is rarely used as a measure of normal plant performance.

Figs. 4 and 5 illustrate the growth of cane and the consistent loss of weight, due to soil moisture utilization in two of the tanks. Fig. 4 gives the history of Tank 13 from July 6 to September 24. The scale on the right, to be used in conjunction with the upper curve, shows variations in weight. During the period

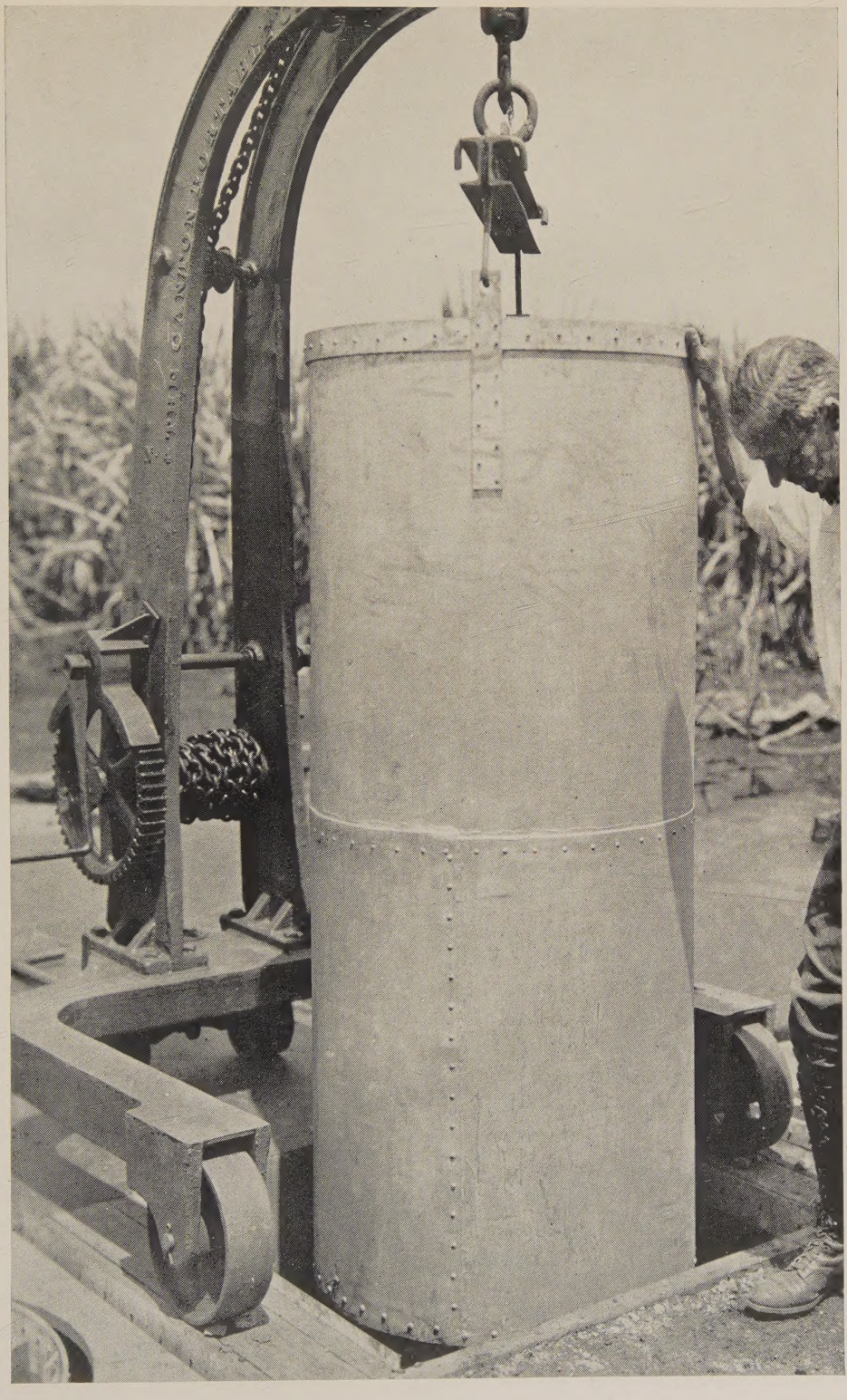

Fig. 3. One of the tanks used in the studies of the water relations of the sugar cane plant. Each tank weighed about one ton when ready for planting.

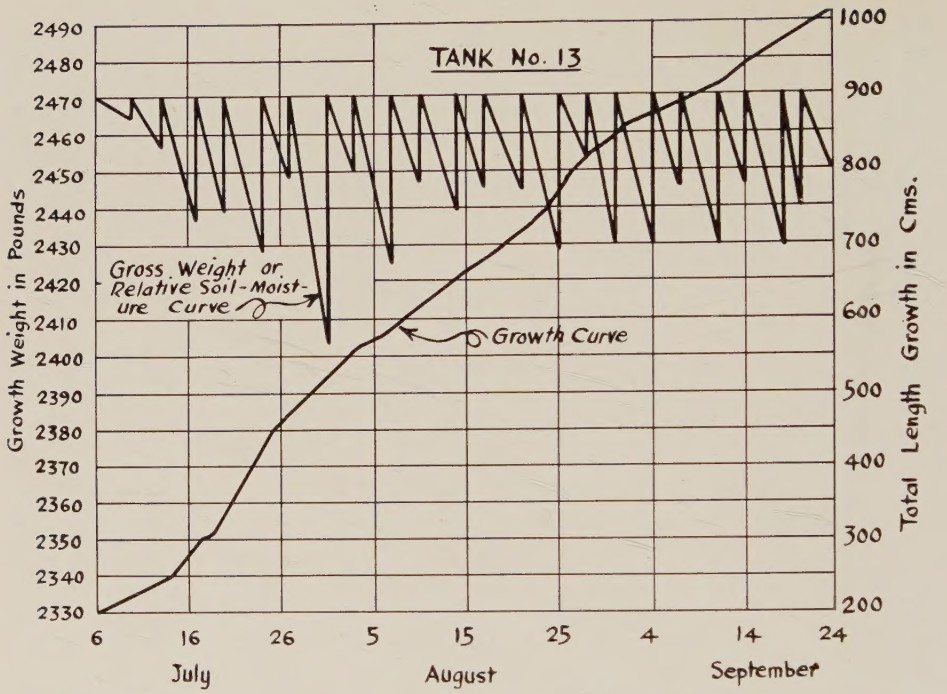

Fig. 4. Growth and soil-moisture history of Tank No. 13. Note the continuous growth of the cane and its independence of soil moisture. Frequent irrigations, as noted by the vertical jumps in the weight curve, kept the moisture above the wilting percentage.

in question the tank was irrigated 22 times, the average interval being about 3 days. It is evident that the vertical lines represent irrigations, since the adjusted gross weight can only increase with additions of water. The slope of the connecting lines indicates the rate at which water was lost between irrigations.

The lower curve, using the right-hand scale, is more significant, however. Here it is seen that length-growth proceeded uniformly and almost regularly from July 6 to September 25. Evidently soil moisture played no part in determining the rate of growth. The minor departures of this line from being perfectly straight are probably caused by variations in temperature.

Quite a different picture is shown in Fig. 5. Tank 4 was allowed to suffer due to a deficiency of soil moisture, the tank being irrigated only 6 times during the same interval. Here the growth curve shows the influence of this deficiency. Getting off to a good start on July 6, the plant grew uniformly until July 14, when it ceased growth and made no more until July 25, the date of the next irrigation. Growth was resumed at once and proceeded normally until August 3, when, after a short transition, growth once more ceased. The fact that in all cases growth is resumed after an irrigation demonstrates that the stopping of growth is due to a deficiency of soil moisture.

It is interesting to note, moreover, that while the cane is growing the rate of growth is about constant for the period during which soil moisture is available; nor does the plant seem to suffer any handicap because of the period of no growth which it may have experienced.

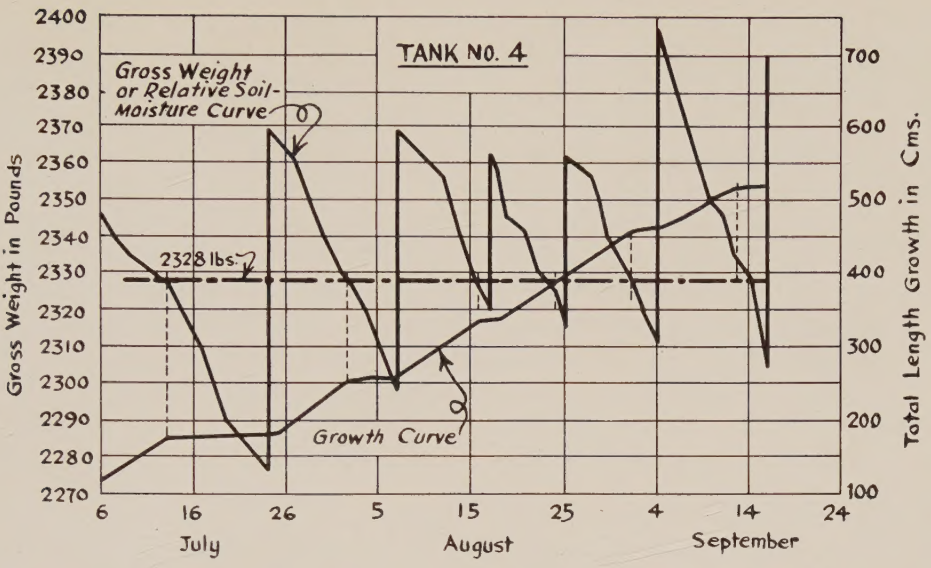

Fig. 5. Growth and soil-moisture history of Tank No. 4. Here the growth is not continuous as in Tank No. 13, but is made up of periods of normal growth and periods of little or no growth. Growth stopped in all cases when the tank weighed 2328 pounds. At this weight the moisture in the soil in the root zone was the wilting point.

Moreover, as indicated in the figure, growth in all cases stopped when the gross weight of the system had dropped to 2,328 pounds. Subsequent observations indicated that the moisture content in the soil in the upper 30 inches in Tank 4 was at the wilting point when the gross weight of the tank had been reduced to 2,328 pounds by the activity of the cane roots.

If the results of these tank studies may be taken as significant (and their similarity to other findings gives support), several far-reaching conclusions may be reached:

(a) There seems to be no advantage in irrigating more frequently than is necessary to keep the cane growing.

(b) If the irrigation interval is greater than that necessary to keep the cane growing, growing time is lost; such a loss of growth is not made up by unusual activity when water is applied.

That these conclusions, reached by a study of isolated cane plants in tanks, are applicable to field conditions, is demonstrated by elaborate studies of plant and water relations on the mainland (9) and by Shaw's (12) comprehensive Field F experiment at Waipio. Similar results have been obtained by Shaw under plantation conditions at the Waialua Agricultural Company.

Water Absorption by the Cane Plant (23)

An additional point of interest with respect to the characteristics of the cane plant was its apparent capacity for absorbing water by its above-ground parts during showers, the conveyance of the water into the roots and its discharge through the roots into the soil. During the early stages of the investigation it was fre-

quently noted that gains of weight in the tanks occurred during showers of rain. Since the most evident reason for this gain was a leaking of water through the seals around the cane sticks, these seals were continually improved as experience was gained. The gains in weight under natural showers and sprinkling continued. The most spectacular case was one in which a gain of 80 pounds was observed after three hours of garden hose sprinkling. In this case the seal was composed of asphalt applied hot in a layer three inches deep over the board covers. When the hose was played on the critical parts of this seal for two hours, no gain of weight was apparent. Moreover, the soil-moisture content in depths six inches below the soil surface was considerably increased; the surface layer of soil was at practically the same moisture content after sprinkling as before.

No explanation which satisfies all the observed conditions has been offered, although Breazeale (2) and others suggest that such absorption and conveyance may take place. In Breazeale's work, the soil involved is extremely dry and the quantities of water moved are small.

It would appear, however, that light rains or showers might have more effect on the cane's well-being than is ordinarily assumed. The problems involved in the study of the conditions necessary for this absorption are of compelling scientific interest as well as of possible commercial importance.

Future Studies

It will be noted that the work reported so far has to do with the formation of cane and not the formation of sugar. A study of the role of soil moisture in cane ripening forms the next logical step in the investigations. General plantation procedure demands the drying-off of a field for some time prior to harvest. Although it is probably true that such a practice improves the quality ratio by drying out the sticks and concentrating the juice, it is by no means clear that additional sucrose is manufactured during this period. Studies with other crops (9), (16) indicate that such important properties as the sugar content of prunes and the drying ratio of peaches is quite independent of the soil moisture content upon which the crops were grown, provided the wilting percentage is not reached.

Drying out a field prior to harvest has unquestionable value in reducing the tonnage of cane that has to be handled per ton of sugar. But such a saving can only be at the expense of growing time. We need more basic information with respect to the effect of soil moisture upon sugar formation before harvesting and milling costs can be balanced against the potential sugar-producing value of the time which is lost by drying off.

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(23) Details of the experimental evidence upon which this paragraph is based have never appeared in printed form. All observations and results, however, are summarized in a memorandum by Shaw to Wadsworth under the date of December 19, 1929. The memorandum is filed as a part of the progress report for Project A-8.

Seedlings for Spreading

The problem of choosing a few seedlings from the many seedlings under trial on plantations for rapid multiplication resolves itself into the degree of confidence we may have in a seedling after seeing its performance in a number of places.

This may be simply expressed by designating those canes which show exceptional worth through observation and preliminary yield data as "ten-acre" canes. In these cases it would seem advisable to extend the canes to approximately ten acres before waiting for yield data from experiments. A second designation of "one-acre" canes would be in order. These would include the seedlings on which the early information was outstanding, but on which insufficient yield data are available at the present time to suggest further expansion. With one acre of a promising seedling planted the stage is then set for a rapid expansion to ten acres or more and to final variety tests should the information continue favorable.

The following list of seedlings are classified according to the above-mentioned scheme.

"TEN-ACRE" SEEDLINGS

H 109 Conditions:

28-1234	(POJ 2364 x 26 C 270)
31-1389	(POJ 2878 x 26 C 270)

Windward Kauai:

Middle Belt Irrigated Lands:	Co. 213	(POJ 213 x Kansar)
	27-3840	(Badila x H 456)
	28-2055	(POJ 2364 x 26 C 270)
Makai Lands:	28-2055	(POJ 2364 x 26 C 270)
	31-1389	(POJ 2878 x 26 C 270)

Hilo District:

Mauka:	Co. 213	(POJ 213 x Kansar)
	Co. 290	(Co. 221 x D 74)
	28-1234	(POJ 2364 x 26 C 270)
	29-3859	(H. Uba x H 456)
Makai:	28-1234	(POJ 2364 x 26 C 270)
	31-1389	(POJ 2878 x 26 C 270)

Hamakua and Kohala Districts:

Mauka:	Co. 213	(POJ 213 x Kansar)
	U. S. 996	(Kassoer)
Middle Belt:	Co. 290	(Co. 221 x D 74)
	28-1234	(POJ 2364 x 26 C 270)
	29-3859	(H. Uba x H 456)
Makai:	28-1234	(POJ 2364 x 26 C 270)
	28-1864	(POJ 2364 x 26 C 270)
	31-1389	(POJ 2878 x 26 C 270)

"ONE-ACRE" SEEDLINGS

H 109 Conditions—Short Cropping:

28-597	(POJ 2364 x D 1135)
893	(POJ 2364 x 26 C 270) for non-eye spot areas
1095	(POJ 2364 x D 1135)
1205	(POJ 2364 x 26 C 270) for non-eye spot areas
1821	(POJ 2364 x Wailuku 11)
1864	(POJ 2364 x 26 C 270) for non-eye spot areas
1931	(POJ 2364 x 26 C 270)
2014	(POJ 2364 x 26 C 270)
2055	(POJ 2364 x 26 C 270)
2096	(POJ 2364 x 26 C 270)
5468	(Str. Mex. x Kohala 73)
29-791	(POJ 2364 x Manoa 301) for non-eye spot areas
6334	(POJ 2364 x 20 S 16)
7273	(POJ 2725 x H 227)
7788	(28-1227 x H 456)
30-748	(POJ 2364 x 26 C 113)

H 109 Conditions:

28-985	(POJ 2364 x D 1135)
2014	(POJ 2364 x 26 C 270)
2055	(POJ 2364 x 26 C 270)
2694	(Yel. Cal. x H 109)
5934	(Yel. Cal. x H 109)
29-6334	(POJ 2364 x 20 S 16)
30-453	(POJ 2364 x Ewa 569)
2417	(28-674 x H 456)
7353	(POJ 2364 x Mak. 3)
31-1236	(POJ 2878 x Cavengerie)
1402	(POJ 2878 x H 9811)
2058	(H 9806 x POJ 2878)
2538	(POJ 2878 x H 7878)
3012	(POJ 2364 x 26 C 270)
3016	(POJ 2364 x 26 C 270)
3040	(POJ 2364 x 27 C 518)

H 109 Conditions—Eye Spot Resistant Canes:

26 C 270	(Yel. Cal. x H 109)
28-2055	(POJ 2364 x 26 C 270)
3540	(Yel. Cal. x H 109)
30-2417	(28-674 x H 456)
4422	(POJ 2364 x H 8988)
31-626	(28-4898 x POJ 2878)
2343	(28-4772 x POJ 2878)
2346	(28-4772 x POJ 2878)
3012	(POJ 2364 x 26 C 270)

Windward Kauai:

Mauka—Middle—Irrigated:

Hawi 10	(Badila x D 1135)
28-1813	(POJ 213 x H 456)
4515	(H. Uba x H 456)

4731	(H. Uba x H 456)
4803	(N. Uba x H 456)
4830	(N. Uba x H 456)
29-3656	(Kassoer x H 9812)
7989	(Kassoer x H 9812)
8045	(POJ 2364 x D 117)
30-4422	(POJ 2364 x H 8988)
31-616	(28-4898 x POJ 2878)
624	(28-4898 x POJ 2878)
701	(N. Uba x POJ 2878)
728	(N. Uba x POJ 2878)
1389	(POJ 2878 x 26 C 270)
2343	(28-4772 x POJ 2878)
2346	(28-4772 x POJ 2878)
2482	(POJ 2878 x Manoa 301)
2563	(POJ 2878 x H 109)

Kauai:

Mauka—Unirrigated:

Co. 213	(POJ 213 x Kansar)
27-3840	(Badila x H 456)
28-2055	(POJ 2364 x 26 C 270)
2321	(Uba x H 456)
4291	(H. Uba x H 456)
4399	(H. Uba x H 456)
4456	(H. Uba x H 456)
4515	(H. Uba x H 456)
4567	(H. Uba x H 456)
4731	(H. Uba x H 456)
29-3614	(Kassoer x H 9812)
3656	(Kassoer x H 9812)
7989	(Kassoer x H 9812)
8045	(POJ 2364 x D 117)
30-3622	(N. Uba x Waialua 8)
31-135	(POJ 2878 x 27-994)
616	(28-4898 x POJ 2878)
701	(N. Uba x POJ 2878)
728	(N. Uba x POJ 2878)
2346	(28-4772 x POJ 2878)

Makai Irrigated:

29-8045	(POJ 2364 x D 117)
30-748	(POJ 2364 x 26 C 113)
2417	(28-674 x H 456)
4422	(POJ 2364 x H 8988)
7353	(POJ 2364 x Mak. 3)
31-1236	(POJ 2878 x Cavengerie)
2343	(28-4772 x POJ 2878)
2346	(28-4472 x POJ 2878)
2482	(POJ 2878 x Manoa 301)
2563	(POJ 2878 x H 109)

Hilo Mauka:

28-1813	(POJ 213 x H 456)
2014	(POJ 2364 x 26 C 270)

2321	(Uba x H 456)
4291	(H. Uba x H 456)
4399	(H. Uba x H 456)
4501	(H. Uba x H 456)
4594	(H. Uba x H 456)
4649	(H. Uba x H 456)
4731	(H. Uba x H 456)
4830	(N. Uba x H 456)
4867	(N. Uba x H 456)
29-3290	(H. Uba x H 456 or D 1135)
3656	(Kassoer x H 9812)
3880	(H. Uba x H 456)
3884	(H. Uba x H 456)
30 H.P. 78	(POJ 2364 x Aiea 165)
31-624	(28-4898 x POJ 2878)
701	(N. Uba x POJ 2878)
2346	(28-4772 x POJ 2878)
2482	(POJ 2878 x Manoa 301)

Hilo Makai:

Co. 290	(Co. 221 x D 74)
28-4731	(H. Uba x H 456)
29-3859	(H. Uba x H 456)
8045	(POJ 2364 x D 117)
8053	(POJ 2364 x D 117)
30-453	(POJ 2364 x Ewa 569)
7353	(POJ 2364 x Mak. 3)
30 H.P. 76	(POJ 2364 x Aiea 165)
78	(POJ 2364 x Aiea 165)
182	(POJ 2364 x H 227)
31-1203	(POJ 2878 x D 117)
2343	(28-4772 x POJ 2878)
2346	(28-4772 x POJ 2878)
2482	(POJ 2878 x Manoa 301)

Hamakua & Kohala:

Mauka—Elevation 1400 ft. up:

Co. 290	(Co. 221 x D 74)
28-2321	(Uba x H 456)
4291	(H. Uba x H 456)
4370	(H. Uba x H 456)
4461	(H. Uba x H 456)
4867	(N. Uba x H 456)
4908	(H. Uba x H 456)
29-3290	(H. Uba x H 456 or D 1135)
3656	(Kassoer x H 9812)
3859	(H. Uba x H 456)
3880	(H. Uba x H 456)
3884	(H. Uba x H 456)
7989	(Kassoer x H 9812)
30-4192	(Uba x K 107)
31-135	(POJ 2878 x 27-994)
624	(28-4898 x POJ 2878)
701	(N. Uba x POJ 2878)

Middle—Elevation 800-1400 ft.:

Co. 213	(POJ 213 x Kansar)
28-1813	(POJ 213 x H 456)
1864	(POJ 2364 x 26 C 270)
2014	(POJ 2364 x 26 C 270)
2055	(POJ 2364 x 26 C 270)
28-4515	(H. Uba x H 456)
4639	(H. Uba x H 456)
4649	(H. Uba x H 456)
4731	(H. Uba x H 456)
4803	(N. Uba x H 456)
4830	(N. Uba x H 456)
4874	(N. Uba x H 456)
5366	(U.D. 23 x Badila)
29-791	(POJ 2364 x Manoa 301)
3207	(H. Uba x H 456 or D 1135)
3290	(H. Uba x H 456 or D 1135)
3656	(Kassoer x H 9812)
3880	(H. Uba x H 456)
3884	(H. Uba x H 456)
7617	(20 M.P. 60407 x 25 C 34)
7989	(Kassoer x H 9812)
8045	(POJ 2364 x D 117)
8053	(POJ 2364 x D 117)
30-453	(POJ 2364 x Ewa 569)
2417	(28-674 x H 456)
4192	(Uba x K 107)
31-624	(28-4898 x POJ 2878)
701	(N. Uba x POJ 2878)
728	(N. Uba x POJ 2878)
2346	(28-4772 x POJ 2878)

Makai—Elevation 0-800 ft.:

28-1095	(POJ 2364 x D 1135)
1813	(POJ 213 x H 456)
2014	(POJ 2364 x 26 C 270)
2055	(POJ 2364 x 26 C 270)
4830	(N. Uba x H 456)
29-3290	(H. Uba x H 456 or D 1135)
3859	(H. Uba x H 456)
7617	(20 M.P. 60407 x 25 C 34)
7788	(28-1227 x H 456)
8045	(POJ 2364 x D 117)
8053	(POJ 2364 x D 117)
30-453	(POJ 2364 x Ewa 569)
2417	(28-674 x H 456)
30 H.P. 78	(POJ 2364 x Aiea 165)
31-701	(N. Uba x POJ 2878)
1236	(POJ 2878 x Cavengerie)
1389	(POJ 2878 x 26 C 270)
2343	(28-4772 x POJ 2878)
2346	(28-4772 x POJ 2878)
2347	(28-4772 x POJ 2878)

Kohala Makai—Short Cropping Varieties:

28-597	(POJ 2364 x D 1135)
893	(POJ 2364 x 26 C 270)
1095	(POJ 2364 x D 1135)
1188	(POJ 2364 x 26 C 270)
1205	(POJ 2364 x 26 C 270)
2014	(POJ 2364 x 26 C 270)
5468	(Str. Mex. x Kohala 73)
29-1570	(POJ 2364 x 26 C 148)
6334	(POJ 2364 x 20 S 16)
7273	(POJ 2725 x H 227)
7617	(20 M.P. 60407 x 25 C 34)
8045	(POJ 2364 x D 117)
8053	(POJ 2364 x D 117)
30-453	(POJ 2364 x Ewa 569)
748	(POJ 2364 x 26 C 113)
30 H.P. 78	(POJ 2364 x Aiea 165)
31-1203	(POJ 2878 x D 117)
1236	(POJ 2878 x Cavengerie)
1389	(POJ 2878 x 26 C 270)
2346	(28-4772 x POJ 2878)
2347	(28-4772 x POJ 2878)
2563	(POJ 2878 x H 109)
3024	(POJ 2364 x 27 C 445)

Hamakua & Kohala—Poor Knoll Canes:

U.S. 996	(Kassoer)
28-4291	(H. Uba x H 456)
29-8510	(U.S. 666 x Self)

A. J. M.
C. G. L.

Manufacturing Qualities of P. O. J. 2878*

By H. F. Hadfield

A request from the Experiment Station, H. S. P. A., Honolulu, for a sample of sugar boiled entirely from an "A" strike of P.O.J. 2878 cane in order to compare its refining qualities with sugar boiled from Yellow Caledonia and other canes, was the incentive to make a few experiments on the qualities of the juice from this cane when crushed alone, as several factories reported its clarifying qualities to be poorer than that of Yellow Caledonia and other canes.

Therefore, on Saturday, February 24, a preliminary four-hour run was made with P. O. J. 2878 alone and the clarifying qualities studied, the juice being treated in the regular way, that is, heated from 212°-216° F. at pH 8.0-8.3.

Several weeks prior to this test, P.O.J. 2878 had been flumed into the mill mixed with Yellow Cadelonia and P.O.J. 36 in the proportion of 25-30 per cent. Under these conditions no difficulty was found in the clarifying qualities of the juice, although the press cake was not quite so porous as usual and at intervals was "sloppy" and the pol higher.

Under ordinary conditions Yellow Caledonia and other canes would clarify in about 45 minutes, with a turbidity reading of 3.5-4.0 cm. When P.O.J. 2878 was crushed alone, however, and limed to pH 8.0-8.3 in the ordinary way, instead of clarifying in 45 minutes at a turbidity reading of 3.5-4.0 cm., it took 2 hours and 28 minutes to settle at a turbidity reading of 2.6 cm. Under these conditions the tonnage of cane per hour had to be reduced and the mills had to shut down in order to clear the settling tanks. During this clarifying test the following data were recorded:

Crusher Juice	Brix	16.59		16.66		17.66	
	Pol	14.89		14.80		16.09	
	App. Pur.	89.75		88.83		91.11	
Mixed Juice	Brix	13.59		13.96		14.34	
	Pol	11.92		12.36		12.83	
	App. Pur.	87.71		88.54		89.47	
	pH	8.8		9.2		8.4	
Last Mill Juice	Brix	3.10		3.30		3.68	
	Pol	2.45		2.52		2.74	
	App. Pur.	79.03		76.36		74.46	
Clarified Juice	Brix	13.44	13.91	13.90	13.88	14.31	14.01
	Pol	11.64	12.29	12.36	12.34	12.76	12.51
	App. Pur.	86.61	88.35	88.92	88.90	89.17	89.29
	pH	7.5	7.9	7.4	7.9	7.8	7.9
	Turbidity, cm.	2.6	2.8	2.0	2.3	2.8	2.6

* A report presented at the Hilo meeting of the A. H. S. T., 1934, through the courtesy of Alex Fraser, Manager of Hilo Sugar Company.

Press Juice	Brix	13.81
	Pol	12.09
	App. Pur.	87.54
	pH	8.5
	Turbidity, cm.	4.0
Press Cake	Pol	4.2
	Bagasse per 100 solids in cake 22.43%.	
Bagasse	Pol	1.08
	Pol	1.39
	Moisture	39.0
	Moisture	43.0
Fiber % Net Cane		11.00%
		10.00%

As it required about a twelve-hour run to clear the factory of Yellow Caledonia juice, etc., in order to boil with certainty an "A" strike of P.O.J. 2878 alone, arrangements were made to flume this cane on Tuesday, February 27. W. L. McCleery, Acting Sugar Technologist of the Experiment Station, H. S. P. A., very kindly consented to be present, and plans were made to make the following experiments:

Condition at the Settlers With P.O.J. 2878 Juice Alone

During the early hours of Tuesday morning, the tonnage of cane per hour was reduced, and six settlers out of thirteen and five presses out of ten were cleaned in preparation for this experiment. At 5:30 a. m. the fluming of P.O.J 2878 alone started. At 8:30 a. m. the six settlers had filled and it was necessary to close the mills down after only a three-hour run. During the rest of the twelve-hour day stops had to be made at intervals amounting to 4 hours and 50 minutes, the tonnage averaging 38.5 per hour.

Experiment 1.

Period of settling—regular practice. Heating 212-216° F., liming 8.0-8.3 pH.

Settler No. 5

Time to fill	7	minutes.
Cold juice pH	8.3	
Clarified juice pH	7.7	
Turbidity, cm.	1.0	after 45 minutes settling.
Cold juice pH	8.3	
Clarified juice pH	7.7	
Turbidity, cm.	1.1	after 55 minutes settling.
Cold juice pH	8.3	
Clarified juice pH	7.7	
Turbidity, cm.	1.5	after 75 minutes settling.
Cold juice pH	8.3	
Clarified juice pH	7.7	
Turbidity, cm.	1.9	after 90 minutes settling.

Experiment 2.

Period of settling—irregular practice.

Dividing the application of lime into two parts: First at 6 pH before heating

and made up to pH 8.3 later; second at 7 pH before heating and made up to pH 8.4 later by adding lime to the settling tanks.

Settler No. 11

Cold juice before heating..... 6.0 pH
Clarified juice after heating..... 8.3 pH
Turbidity, cm. ..... 1.5 after 1-1½ hours settling.

Settler No. 12

Cold juice before heating..... .... 6.0 pH
Clarified juice after heating..... 8.4 pH
Turbidity, cm. ..... 1.5 after 1-1½ hours settling.

Settler No. 10

Cold juice before heating..... 7.0 pH
Clarified juice after heating..... 8.3 pH
Turbidity, cm. ..... 2.0 after 1-1½ hours settling.

Settler No. 11

Cold juice before heating..... 7.0 pH
Clarified juice after heating..... 8.0 pH
Turbidity, cm. ..... 1.5 after 1-1½ hours settling.

In all four cases the volume of settlings prevented the opening of the lower juice valve into the clear flume line to the evaporators.

Experiment 3—Double Superphosphate as a Clarifying Agent.

In this experiment 5-, 10- and 15-pound portions of double superphosphate were added (in Settlers Nos. 12, 13 and 1 respectively) to the juice with the liming and heating under regular practice.

Settler No. 12 **Five Lbs. D. S. Phos.**

Cold Juice ..... 8.3 pH
Hot limed juice ..... 8.0 pH Before phos. was added.
Clarified juice ..... 7.6 pH After phos. was added.
Turbidity ..... 1.4 cm. After 55 min. settling.

Settler No. 13 **Ten Lbs. D. S. Phos.**

Cold juice ..... 8.3 pH
Hot limed juice ..... 8.0 pH Before phos. was added.
Clarified juice ..... 7.5 pH After phos. was added.
Turbidity ..... 1.7 cm. After 47 min. settling.

It was necessary to add a little more lime after the addition of phosphate to increase the pH to 7.5.

Settler No. 1 **Fifteen Lbs. Phos.**

Cold juice ..... 8.3 pH
Hot limed juice..... 7.8 pH Before phos. was added.
Clarified juice ..... 7.2 pH After phos. was added.
Turbidity ..... 1.5 cm. After 45 min. settling.

It was necessary to add a little more lime after the addition of phosphate to increase the pH to 7.2.

In all three cases the volume of settlings prevented the opening of the lower valve into the clear flume line to the evaporators.

Experiment 4—Addition of Bagasse Screenings to the Juice after Liming and Heating in the Ordinary Way.

Screenings were added slowly into the settling tank as it filled with the juice.

Cold juice	8.3 pH
Clarified juice	7.8 pH
Turbidity	1.0 cm.

The juice was cloudy and a great deal of the bagasse screenings would not settle and floated to the top. Juice from the second valve was very dark and the bagasse screenings did not carry the impurities to the bottom.

During these tests the following data were recorded for the twelve-hour run on P.O.J. 2878 alone:

Crusher Juice	Brix	16.72
	Pol	14.92
	App. Pur.	89.23
Mixed Juice	Brix	13.34
	Pol	11.69
	App. Pur.	87.63

Suspended solids in juice 0.229, 0.176, 0.167, 0.218.
Average 0.197

Last Mill Juice	Brix	3.50
	Pol	2.49
	App. Pur.	71.14
Bagasse	Pol	1.22
	Sol. non-sugars	0.495
	Moisture	41.21
	Fiber %	57.075
	Bag. % cane	20.64
	Extraction	98.06
Fiber % Net Cane		10.00%
		12.00

Dilution	26.61% N. J.
Cane Ratio	8.12
Quality Ratio	8.85
Field Trash	2.00% approximately.
Ab. Juice Factor	101

Experiment 5—Presses.

During the tests on clarification, tests were also made at the presses on the settlings with bagasse screenings.

No. 6 Press—Without bagasse screenings on P. O. J. 2878 settlings alone:

Pol of cake	7.4	5.9
Moisture of cake	76.8	82.00

Per cent bagasse per 100 solids 20.69 and 26.29.
Press cake very sloppy.

No. 3 Press—With 5 lbs. bagasse screenings per settler.
(Capacity of settler 270 cubic feet.)

Pol of cake	3.0	3.7
Moisture of cake	85.1	85.88

Per cent bagasse per 100 solids 34.59 and 33.54.
Press cake sloppy.

Experiment 6—Sugar.

Grain was small.
Strike "A" grained (without seed).
Color lighter than usual.
Pol 98.3.
No purging.
Ash 0.28 per cent.
Per cent suspended solids 0.046.

Summary

The tests seemed to indicate that:

1. To divide the application of lime before and after heating is beneficial in the settling of juices, but the volume of settlings was so great that the juice from the lower valve of the settling tank was never clear.

2. To add double superphosphate to the limed juice is beneficial in settling the juice and gave a lighter color than in the case of the test where the application of lime was divided. The volume of settlings, however, was the same, and the juice from the lower valve of the settling tank was never clear.

3. The addition of bagasse screenings to the juice in the settlers was not beneficial from the clarification standpoint. Fine bagasse added to the settlings just prior to filtration materially reduced pol in cake.

4. When P.O.J. 2878 was crushed alone, the juice required, after liming and heating in the ordinary way, over one hour to clarify to a very poor turbidity of 1.5 cm.

5. When P.O.J. 2878 is mixed with other canes such as Yellow Caledonia and P.O.J. 36 in the proportion of 25 to 30 per cent, clarification is just as good as that of Yellow Caledonia or P.O.J. 36 alone. The presses, however, do not function as well, and though the press cake is fairly firm the pol is usually higher.

Phosphate Fixation in Hawaiian Soils — II

By Arthur Ayres

The first of a series of papers (2) on the subject of phosphate fixation appeared under the above title in a recent issue of this publication. It is the plan of the author, Francis E. Hance, to have succeeding papers presented by members of the staff as their researches become available for publication. The following presentation constitutes the second paper of this series.

The recognized importance of the phenomenon of phosphate fixation to agriculture has led, in recent years, to world-wide investigation of the subject. That greater unity of thought does not exist among the numerous investigators as to the precise nature of the chemical processes involved is due in part to the greatly diverse soil types available for study. Many constituents of a soil are capable of rendering phosphates insoluble. Considered individually, certain of the reactions by which fixation takes place are understood, while others remain relatively obscure. The complexity of the problem lies essentially in the fact that fixation by such a heterogeneous mixture as a soil involves simultaneously a large number of reactions, both physical and chemical, which occur at different rates and in widely varying degree in different soils.

Until very recent years the subject of fixation of phosphates by soils had received practically no attention at this Station. That fixation occurs in Hawaiian soils, however, and that something of the extent to which it occurs were realized, at least as early as 1902, is evidenced by a publication of that date by J. T. Crawley (1). Twenty years later, McGeorge (3) showed that phosphates were susceptible to fixation by Hawaiian soils from dilute solutions of acids and bases. Absorption from weak solutions of various acids was further studied in this laboratory by R. R. Ward and P. L. Gow in connection with their investigation of the Demolon and Barbier method of soil phosphate evaluation. At the present time various aspects of the problem are being investigated by L. E. Davis and the writer, as indicated by Hance (2) in a recent issue of *The Hawaiian Planters' Record*.

A phase of the general study which is of particular importance in Hawaii is that of the extent to which fixation of phosphates occurs in the many and varied soil types comprising our agricultural lands. Numerous Hawaiian soils, although admittedly deficient in available phosphates as indicated by crop response to this nutrient, nevertheless fail to show improved yields following moderate applications of soluble phosphatic fertilizers. Yet, the fertility of these same soils may be definitely enhanced through the addition of phosphate in amounts greatly in excess of current crop requirements. However, the failure to obtain response to moderate treatments of phosphate on areas deficient in this nutrient does not necessarily indicate high fixation. It therefore becomes a matter of very practical importance to know whether the failure of the cane crop to respond to normal applications of phosphate, on phosphate deficient areas, is due to excessive fixation or to some other

limiting factor. Much can be accomplished in this direction through correlating the fixing power of the soils with the observations of agriculturists relative to response to phosphate fertilization under field conditions. Such a study involves first, the development of a satisfactory laboratory method for measuring fixation; and, second, an investigation of the extent to which fixation occurs. It is the purpose of this paper to present the results of inquiry into these and closely related matters.

Experimental

The opinions of investigators have differed as to the most satisfactory means of determining the ability of a soil to fix phosphates. A device which has been used for this purpose consists in the percolation of a phosphate solution of known concentration through a column of soil and subsequent analysis of the percolate. Another procedure involves agitation of the soil with a solution of phosphate, the extent of fixation being calculated from the initial and final concentrations of phosphate in the solution. A third method employed to the same end consists in intimately mixing the desired amount of a soluble phosphate with a given weight of soil and maintaining the mixture in a moist condition for a period of time sufficient to effect fixation. In the last case the unfixed phosphate is removed from the mixture for determination either by extraction or by dialysis. The absorbed phosphate in all of these methods is measured indirectly, that is, as the difference between the quantity added to the soil and the amount remaining unfixed at the end of a given period. Certain procedures are better suited than others to the investigation of a particular phase of the subject. For the study in hand, involving the evaluation of a relatively large number of soils, a method has been developed in this laboratory which consists basically in the mechanical agitation of the soil-phosphate solution mixture for a definite period, followed by filtration under gravity and subsequent analysis of the filtrate.

Much of the work which has been done on fixation has involved absorption of the phosphate from weak solutions of acids. In order to more nearly simulate the conditions under which fixation occurs in the field the reactions in the present investigation were brought about in solutions of approximate neutrality.

The nature of many Hawaiian soils is such that when suspended in neutral solutions of very low electrolyte content filtration is extremely difficult. In such cases the task of effecting a separation of the solution from the soil becomes a very laborious and greatly protracted one, even when recourse is had to filtration under suction, or to the Chamberland (porcelain) filter utilizing a pressure of one hundred pounds per square inch. Dialysis likewise is a very slow process and not well suited to the present work. However, this difficulty was overcome by the use of an electrolyte (ammonium chloride) in amount equal to one per cent by weight of the phosphate solution. In the resulting flocculation the highly dispersed soil particles are rendered incapable either of passing through the filter or of preventing the passage of the solution. A partial and desirable precipitation of colloidal organic matter also results from the presence of the salt. Ammonium chloride increases somewhat the absorption of phosphate by our soils. This observation, which is of interest in view of the extensive use by the plantations of similar salts as sources of

plant nutrients, will be investigated in the near future; doubtless it is brought about in part through the mechanism of base exchange. While, as stated, this substance tends to increase the fixation of phosphate, it is not felt that its use in this work detracts from the value or significance of the results, the essential purpose of which is to show the relationship of one soil to another with respect to fixation. Furthermore, the same effect is no doubt obtained, although probably in lesser degree, under actual field conditions.

The phosphate solutions employed in the study were prepared from diammonium phosphate and ammonium chloride. Prior to extraction by the soil the acidity of all solutions used was adjusted with hydrochloric acid to a point just under neutrality (pH = 6.8). Preparation of the soils consisted in air drying, pulverizing, and passing through a 2 mm. screen. Extraction was accomplished by continuous agitation of the soil and phosphate solution mixture (ratio = 1:10) for a period of 24 hours. Immediately following this operation a portion of the solution sufficient for analysis was filtered off. The first portion of the filtrate was discarded in order to preclude the possibility of error through adsorption of phosphate on the filter.

Rate of Fixation:

It will be noted that the procedure developed for comparing the fixing power of soils involved the agitation of the soil and phosphate solution for a period of 24 hours. It should not be inferred from this statement, however, that fixation is complete at the end of that time. The period required for the attainment of a true equilibrium between a soil and soluble phosphate which has been added to it will depend upon the nature of the soil, the magnitude of the application, and the manner in which the resulting fixation is brought about.

A study was therefore made of the rate at which fixation occurs under the conditions of the experiment. For this work three soils of widely differing chemical properties were chosen: (a) a Waipio Substation soil; (b) a specimen from upland windward Kauai; and (c) a sample from the Hilo Coast region of Hawaii. From 10 - 12 extractions were made in the case of each of these soils, the period thereof varying from 5 minutes to 48 hours. A soil-solution ratio of 1 to 10 was used, soil and phosphate solution being employed in amounts of 50 grams and 500 milligrams, respectively. This corresponds to a treatment of 25,000 pounds P_2O_5 per acre-foot of soil*. While it may appear unreasonable to treat soils with phosphate in such large amount, even in the laboratory, it becomes necessary for the satisfactory study of our highest-fixing soils. This point is clearly illustrated in Table I, and, graphically, in Fig. 1.

* This figure is based upon the value of 2,500,000 pounds air-dry soil per acre-foot.

TABLE I

RATES OF PHOSPHATE FIXATION BY HAWAIIAN SOILS

Time	Soil 9103 Waipio Substation mg P_2O_5		Soil 9077 Upland Windward Kauai mg P_2O_5		Soil 8922 Hilo Coast mg P_2O_5	
	In soln.	Fixed	In soln.	Fixed	In soln.	Fixed
0	500	0	500	0	500	0
5 min.	388	112	338	162	168	332
15 "	377	123	304	196	95	405
30 "	369	131	282	218	53	447
1 hr.	360	140	258	242	35	465
2 "	353	147	238	262	23	477
5 "	340	160	210	290	...	...
5.5 "	...	...	208	292	8	492
12 "	332	168	192	308	5	495
20 "	324	176	172	328	4	496
24 "	...	...	169	331	3	497
32 "	318	182	157	343	2	498
48 "	310	190	142	358	1	499

Referring to the chart, we observe that fixation proceeds at a tremendous rate during the first hour, the Hilo Coast soil absorbing 93 per cent of the added phosphate during that brief period. After the first hour the rate gradually drops off, becoming practically constant after 12 hours and remaining thus for the remainder of the period during which observations were made. Recent investigation by Davis, cited by Hance (2), of a high-fixing Manoa Valley soil indicates that equilibrium is not reached even after several weeks of continuous agitation of the soil-phosphate solution mixture. It thus becomes obvious that in a study of the fixing capacities of a relatively large number of soils the attainment of a true equilibrium is exceedingly impractical. Neither is it essential, for at the end of 24 hours, the data show fixation in the case of all three soils was proceeding at a very slow and constant rate. After due consideration of the factors involved, this period of extraction (24 hours) was chosen for the comparative study. Subsequent experiments have shown that results obtained upon this basis are wholly reproducible.

The fine state of subdivision of the soil, together with the constant mechanical agitation of the soil-phosphate solution mixture, offer conditions especially conducive to the rapid fixation of the phosphate. While it is desirable for the purposes of this study that such should be the case, the rates thus determined may not be taken as absolute measures of fixation under field conditions.

The writer has attempted to determine the rate at which fixation occurs when soluble phosphate is intimately mixed with a moist soil and allowed to stand. Fixation under such conditions more nearly approximates the process as it occurs in the field than is the case where the soil is constantly agitated with a large volume of phosphate solution. Such studies have not, however, been as successful as might be desired, for, in order to finally separate, for determination, the unfixed phosphate from the treated soil, it is necessary either to extract or dialyse the mixture. And in so doing it is impossible to be certain that one has effected a separation of

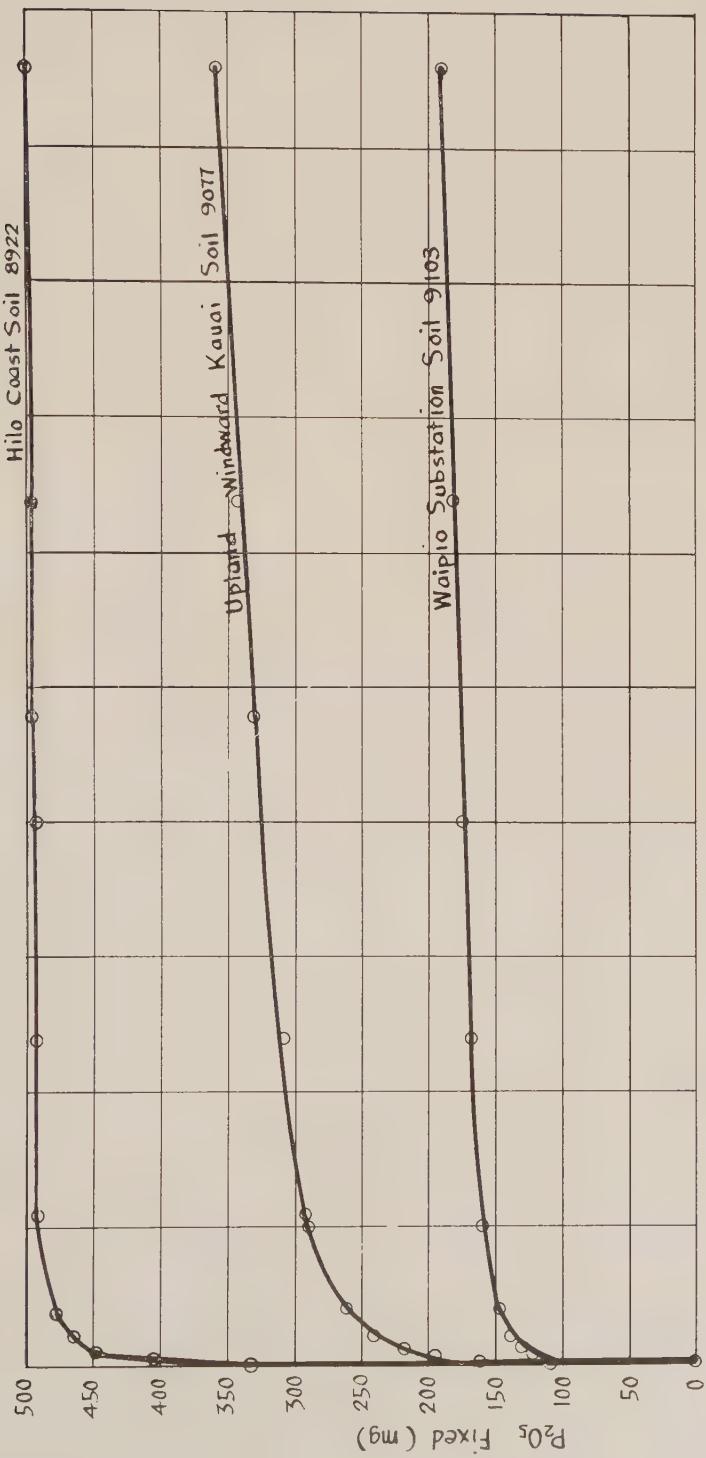

Fig. 1. Rates of phosphate fixation by typical Hawaiian soils. Ratio of soil to solution—1:10. P_2O_5 initially present in solutions=500 mg.

the unfixed from the fixed phosphate without either increasing or reversing the fixation.

Our laboratory studies suggest that the rate at which a given amount of soluble phosphate will become fixed under field conditions will depend upon the quantity of soil with which the phosphate is brought into intimate contact. Thus, for example, if one pound of phosphate is mixed with one thousand pounds of a moist soil, fixation will proceed at a more rapid rate than would be the case were the same quantity of phosphate mixed with but one hundred pounds of the soil. Experimentally, it was found that when a soil was treated with phosphate under the laboratory conditions already described, and at the rate of 2,500 pounds P_2O_5 per acre-foot, all of the added phosphate had become fixed within a period of four hours. When, however, an equal quantity of the soil was treated with ten times this amount of phosphate, or at the rate of 25,000 pounds per acre-foot, all other conditions being identical, fixation at the end of four hours amounted to but 70 per cent of the total. Reasoning by analogy we see that were 2,500 pounds of phosphate applied to one-tenth the amount of soil and solution employed in the first instance, fixation at the end of the 4-hour period, instead of being complete, would have amounted to but 70 per cent. The data further showed that before many more hours had elapsed, in the case of the larger treatment, the rate of fixation had greatly diminished, with indications that weeks or months would be required to complete the process. Now, when soluble phosphate is concentrated in the soil as, for instance, when it is applied in the line ahead of planting instead of being intimately mixed with the surface foot of soil it is brought into contact with but a minute fraction thereof. In such a case, assuming fertilization at the rate of 250 pounds P_2O_5 per acre, the relative quantities of phosphate and soil *in the zone of contact* would correspond not to this treatment, but to one of many thousands of pounds of P_2O_5 per acre-foot. Thus it is apparent that the result of restricting the zone of phosphate application is to effectively retard fixation. It follows that the *rate at which phosphate will undergo fixation in the field will be governed in large part by the manner in which it is applied.*

Treatment:

The value of a method which measures the properties of a soil depends upon the conditions of the test being identical in all cases. For example, devices such as the citric acid method of soil nutrient evaluation, tests for soil acidity and field experiments yield results which, though purely relative, nevertheless provide a basis for soil comparison and classification. So also, in preparing to determine their fixing power it became necessary to settle upon a definite phosphate treatment which would be applicable to all soils of the Islands. Following much preliminary experimentation a standard treatment was chosen consisting of 500 milligrams phosphoric acid (P_2O_5) as diammonium phosphate per 50 grams air-dry soil, which is the approximate equivalent of 25,000 pounds P_2O_5 per acre-foot. The selection of this very large standard treatment was based upon two observations: (a) that lesser quantities of phosphate are almost completely absorbed by our highest fixing soils, thereby defeating the purpose of the test; and (b) that more satisfactory differentiation between soils results from the use of large amounts of phos-

phate. These facts are clearly evidenced in Fig. 2, where are shown the results obtained by treating a group of higher fixing soils with amounts of phosphate ranging from 2,500 pounds to 25,000 pounds P_2O_5 per acre-foot.

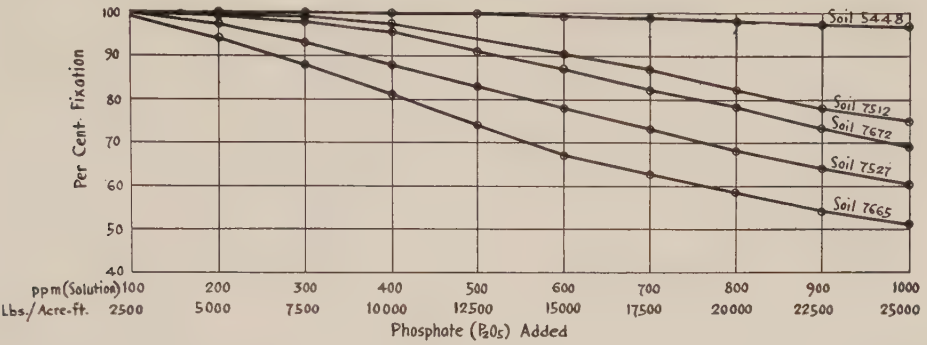

Fig. 2. Showing the differentiation obtained in the study of the fixing power of soils by the use of high phosphate treatments. Ratio of soil to solution=1:10. (Period of extraction=6 hours.)

All of these soils fixed between 98.8 and 100 per cent of the minimum application. On this basis it would be necessary to conclude that the fixing powers of these soils are identical. That such is clearly not the case is brought out by treatment with larger amounts of phosphate. When the application was increased to ten times the minimum, or 25,000 pounds, these same soils showed pronounced differences in fixing power. As treatment was increased, the highest fixing group of soils (represented by No. 5448 in the figure) continued to absorb practically all of the added phosphate. In contrast the percentage fixed by the other soils variously dropped off with each succeeding increment of P_2O_5 until at the maximum some indicated little more than 50 per cent fixation. Thus, by the use of this high treatment we have magnified our scale to the point where may be clearly distinguished differences in fixing power which do not appear following treatment with moderate quantities of phosphate.

It was felt that the purpose of the investigation would be better served and the objective more readily reached if, instead of attempting the tremendous task of evaluating the phosphate-fixing capacity of Hawaiian soils in general, our efforts were devoted to a comparatively detailed study of the soils of a few representative localities. The group finally selected comprised principally soils from the island of Kauai and the Hilo Coast region of Hawaii. The collection was amplified by a few specimens from Oahu and Maui. Previous tests by the fixation field kit, described by Hance (2), and experiences of agriculturists led us to believe that the material thus selected rather generally covered the range from the very high fixing soils to the class in which this property is not a problem. Specimens of soils originating in large part from coral formations are not included in the present investigation.

The comparative fixing powers of these soils, as measured by the method described in preceding pages, are given in Table II. The data are recorded in three forms: (a) as the concentration of P_2O_5 remaining in the solution at the end

of the period allowed for fixation, (b) as the number of pounds of P_2O_5 fixed by the soil, and (c) as the per cent of the added phosphate fixed. The soils listed in the table are, without exception, surface soils, and the order in which they there appear corresponds to their fixing power relative to the group as a whole.

TABLE II

CLASSIFICATION OF SOILS ACCORDING TO THEIR PHOSPHATE FIXING POWER

(Treatment=25,000 Lbs. P_2O_5/Acre-foot)*

Soil	Description of Soils	Final conc. P_2O_5 in soln. (ppm)	P_2O_5 Fixed Pounds	P_2O_5 Fixed Per cent
9103	Waipio Substation—Lowland	650	8,750	35.0
9104	Waipio Substation—Lowland	613	9,675	38.7
8233	West Maui—Lowland	558	11,050	44.2
8940	Leeward Kauai—Lowland	540	11,500	46.0
8938	Leeward Kauai—Lowland	523	11,925	47.7
8975	Leeward Kauai—Lowland	520	12,000	48.0
8977	Leeward Kauai—Lowland	515	12,125	48.5
8980	Leeward Kauai—Lowland	500	12,500	50.0
9201	Experiment Station Field—Lowland	485	12,875	51.5
8931	Central Kauai—Lowland	460	13,500	54.0
9200	Experiment Station Field—Lowland	455	13,625	54.5
8959	Windward Kauai—Lowland	438	14,050	56.2
9121	Central Maui—Lowland	433	14,175	56.7
8961	Windward Kauai—Lowland	428	14,300	57.2
8932	Central Kauai—Lowland	425	14,375	57.5
8979	Leeward Kauai—Lowland	420	14,500	58.0
8948	Central Kauai—Lowland	418	14,550	58.2
8968	Windward Kauai—Lowland	415	14,625	58.5
8976	Leeward Kauai—Lowland	408	14,800	59.2
8946	Central Kauai—Lowland	405	14,875	59.5
8930	Central Kauai—Lowland	403	14,925	59.7
8966	Windward Kauai—Lowland	398	15,050	60.2
8945	Central Kauai—Lowland	393	15,175	60.7
8983	Leeward Kauai—Lowland	390	15,250	61.0
8981	Leeward Kauai—Middle	375	15,625	62.5
8929	Central Kauai—Lowland	375	15,625	62.5
8970	Windward Kauai—Upland	353	16,175	64.7
9110	Windward Kauai—Upland	347	16,325	65.3
9077	Windward Kauai—Upland	337	16,575	66.3
8978	Leeward Kauai—Middle	335	16,625	66.5
8950	Central Kauai—Upland	323	16,925	67.7
8952	Central Kauai—Upland	320	17,000	68.0
8949	Central Kauai—Upland	305	17,375	69.5
9111	Windward Kauai—Upland	297	17,575	70.3
8969	Windward Kauai—Middle	270	18,250	73.0
8962	Windward Kauai—Lowland	263	18,425	73.7
8971	Windward Kauai—Upland	255	18,625	74.5
8934	Central Kauai—Upland	242	18,950	75.8
8944	Central Kauai—Upland	240	19,000	76.0
8965	Windward Kauai—Upland	230	19,250	77.0

* Based upon estimate of 2,500,000 pounds air-dry soil per acre-foot.

8936	Central Kauai—Upland	215	19,625	78.5
8943	Central Kauai—Upland	213	19,675	78.7
8955	Central Kauai—Upland	209	19,775	79.1
8933	Central Kauai—Upland	188	20,300	81.2
8942	Central Kauai—Upland	185	20,375	81.5
8953	Central Kauai—Upland	185	20,375	81.5
8956	Windward Kauai—Upland	185	20,375	81.5
8941	Leeward Kauai—Upland	89	22,775	91.1
7669	Leeward Kauai—Middle	75	23,125	92.5
8958	Windward Kauai—Upland	68	23,300	93.2
8986	Leeward Kauai—Upland	56	23,600	94.4
8861	Hilo Coast—Lowland	38	24,050	96.2
7852	Manoa Substation, Oahu	34	24,150	96.6
8916	Hilo Coast—Lowland	20	24,500	98.0
8915	Hilo Coast—Lowland	19	24,525	98.1
8918	Hilo Coast—Lowland	18	24,550	98.2
8914	Hilo Coast—Lowland	17	24,575	98.3
8917	Hilo Coast—Lowland	17	24,575	98.3
8879	Hilo Coast—Middle	14	24,650	98.6
8893	Hilo Coast—Lowland	14	24,650	98.6
8913	Hilo Coast—Lowland	13	24,675	98.7
8868	Hilo Coast—Middle	11	24,725	98.9
8867	Hilo Coast—Middle	10	24,750	99.0
8919	Hilo Coast—Lowland	10	24,750	99.0
8924	Hilo Coast—Upland	10	24,750	99.0
8858	Hilo Coast—Lowland	9	24,775	99.1
8921	Hilo Coast—Upland	9	24,775	99.1
8920	Hilo Coast—Upland	8	24,800	99.2
8871	Hilo Coast—Upland	8	24,800	99.2
8889	Hilo Coast—Upland	8	24,800	99.2
8887	Hilo Coast—Lowland	7	24,825	99.3
8922	Hilo Coast—Upland	6	24,850	99.4
8925	Hilo Coast—Upland	6	24,850	99.4
8898	Hilo Coast—Lowland	5	24,875	99.5
8882	Hilo Coast—Lowland	4	24,900	99.6

Note: "Central Kauai" refers to the approximate center of the sugar-producing belt of that island.

Classification

Reference to Table II shows that of the seventy-five soils examined, specimens from the Waipio Substation possess the least tendency to fix phosphates, absorbing only slightly in excess of one-third of the amount applied. Next in order is a lowland Maui soil, followed by a group of very productive soils from the dry, leeward side of Kauai. Indicating slightly greater fixation are the Experiment Station fields and certain of the strictly lowland areas of central and windward Kauai. These soils, plus those of lower elevation on Kauai generally, cover the range of fixation from the minimum to 65 per cent. At the latter value are first encountered the upland soils of Kauai. These almost exclusively fill the gap from 65 to where is found at 96 per cent the lowest fixing soils of the Hilo Coast group. Comparable in fixing power with soils of the latter type is the infertile Manoa Substation soil. The greatest fixing power was found in the soils of the Hilo Coast, all specimens from this region fixing above 96 per cent of the added phosphate.

A group of four unusually high fixing Kauai soils (c.f., fixation values 91.1-94.4 per cent in Table II) constitute a noteworthy departure, with respect to this property, from the other soils of that Island. Of these four specimens, two were obtained from abandoned, extreme upland cane fields. One was taken from, and is typical of, the barren soil found on the Kokee road well above the uppermost fields of the Kekaha Sugar Co., Ltd. The fourth represents a growth failure area (middle belt) on the leeward side of the Island.

It is very probable that an extended survey of Hawaiian soils would result in the finding of specimens lower in fixing power than any examined in the course of this study. At the same time there is excellent reason for believing that all of our soils are capable of fixing this nutrient in relatively large amounts.

Fixing Power of Subsoils:

The surface soils of the upland areas of the Kauai rain belt region are in large measure very shallow, being in some instances but a few inches in depth. The point of application of phosphates in soils which fix this nutrient is of very practical importance. The placement of phosphatic fertilizer relative to the subsoil would become of obvious importance were investigation to reveal marked differences in the fixing power of surface and subsoils. Believing that such information should be obtained, a study was made of the subject, employing the technic already described. The resulting data have been augmented by a supplementary investigation of fixation at lower phosphate-to-soil ratios. A comparison of the fixing powers of surface and corresponding subsoils is given in Table III.

TABLE III

FIXATION BY SURFACE SOILS AND SUBSOILS COMPARED
ISLAND OF KAUAI

Soil	Description of Soil	Lbs. P_2O_5 Remaining Unfixed Following Treatment at Rate of: 2,500 Lbs./Acre	7,500 Lbs./Acre	*Index Per Cent Fixation
8959	Windward Kauai—Lowland, surface..	25.0	....	56.2
8960	Windward Kauai—Lowland, subsoil..	5.0	....	72.5
8948	Central Kauai—Lowland, surface....	30.0	....	58.2
8947	Central Kauai—Lowland, subsoil.....	2.5	....	67.7
8930	Central Kauai—Lowland, surface.....	....	475	59.7
8928	Central Kauai—Lowland, subsoil.....	....	30	70.8
8966	Windward Kauai—Lowland, surface..	....	525	60.2
8967	Windward Kauai—Lowland, subsoil..	....	15	77.5
8981	Leeward Kauai—Middle, surface.....	15.0	....	62.5
8982	Leeward Kauai—Middle, subsoil.....	5.0	....	69.7
8970	Windward Kauai—Upland, surface...	....	425	64.7
8973	Windward Kauai—Upland, subsoil...	....	10	84.1
8950	Central Kauai—Middle, surface.....	5.0	....	67.7
8951	Central Kauai—Middle, subsoil.....	2.5	....	73.3

* Values in this column represent fixation under "standard conditions."

8962	Windward Kauai—Lowland, surface..	....	125	73.7
8963	Windward Kauai—Lowland, subsoil..	....	13	84.0
8971	Windward Kauai—Upland, surface...	....	125	74.5
8972	Windward Kauai—Upland, subsoil...	....	8	90.7
8965	Windward Kauai—Upland, surface...	....	100	77.0
8964	Windward Kauai—Upland, subsoil...	....	8	92.8
8936	Central Kauai—Upland, surface.....	....	75	78.5
8937	Central Kauai—Upland, subsoil.....	....	20	91.0
8955	Central Kauai—Upland, surface.....	2.5	....	79.1
8954	Central Kauai—Upland, subsoil.....	0	....	95.6
8956	Windward Kauai—Upland, surface...	5.0	....	81.5
8957	Windward Kauai—Upland, subsoil...	2.5	....	89.9

The figures in the third column of the table, indicating "per cent fixation" are those derived from treatment with the standard amount of phosphate, i. e., 25,000 pounds P_2O_5 per acre-foot of soil. In the first and second columns are shown, in pounds, the quantities of phosphate remaining unfixed subsequent to treatments of 2,500 and 7,500 pounds P_2O_5, respectively. Examination of the data in the first column shows that in the case of every pair of soils thus studied the ability of the subsoil to absorb phosphates far exceeded that of the surface soil. This fact becomes strikingly evident when we examine the results obtained through treatment at the rate of 7,500 pounds P_2O_5. Under these conditions the phosphate remaining unfixed in the case of surface soils amounts to from four to forty times the quantity unfixed by corresponding subsoils. Carrying the results of our laboratory work to the field we conclude that phosphate applied within the surface soil will be far more available than if placed in the higher fixing subsoil. Whether or not, in a specific case, it will be practical to place the phosphate entirely within the surface soil will depend in large part upon the relative proportions of the nutrient-absorbing roots in the two horizons.

Total Fixing Capacity of a Soil:

The query is frequently made: "How much phosphate would it require to completely overcome the capacity of a soil to fix phosphates?" The answer to this question is implied by the following observations: A low fixing soil (c.f., 8233 in Table II) was treated with ammonium phosphate in amounts ranging up to 125,000 pounds P_2O_5 per acre-foot. Of the maximum treatment, 17 per cent was fixed under the conditions of the experiment. Above 10,000 pounds P_2O_5, this soil absorbed a definite proportion (approximately 7 per cent) of each added increment of phosphate until the above stated maximum had been reached. Hence, although the proportion of the total added phosphate fixed decreased as the treatment was increased, nevertheless, the total quantity absorbed became greater with increased application. The quantity of phosphate required to completely overcome the ability of a colloidal soil to fix this material appears then to be indeterminate, total fixation increasing as the concentration of P_2O_5 in the contacting solution is increased, probably up to the limits of solubility of the phosphate.

While the subject is of importance theoretically, indicating something as to the nature of fixation, it is without practical application. The fundamental question with which the agriculturist is concerned becomes, *"What is the minimum amount of phosphate necessary to add to a particular soil in order to establish and maintain in the soil solution a concentration of phosphate sufficient to meet the needs of the current crop?"* It thus becomes apparent that we are not from a practical standpoint concerned with the total fixing capacities of soils. Rather we are interested in determining that portion of a standard phosphate treatment which remains unfixed, or being fixed, is yet able to rapidly reenter the soil solution as the nutrient is withdrawn from that medium either by the cane roots or by leaching. It will be of interest to compare a "high"- and a "low"-fixing soil on the basis of the phosphate remaining unfixed subsequent to treatments of various magnitudes. This comparison is accomplished in Table IV and, graphically, in Fig. 3.

TABLE IV

COMPARISON OF AMOUNTS OF P_2O_5 REMAINING UNFIXED FOLLOWING EXTRACTION OF PHOSPHATE SOLUTIONS OF VARIOUS CONCENTRATIONS BY A "HIGH" AND BY A "LOW" FIXING HAWAIIAN SOIL

100 p.p.m. =0= 2,500 Lbs./Acre-foot (Period of Extraction=6 Hrs.)

Initial conc. P_2O_5 (p.p.m.)	Final conc. P_2O_5 (p.p.m.) Soil 8233	Final conc. P_2O_5 (p.p.m.) Soil 5448
0	< .1	0.0
100	5.	0.0
200	32.	0.0
300	83.	0.3
400	148.	1.5
500	225.	4.0
600	298.	7.0
700	....	10.
800	455.	16.
900	535.	22.
1000	608.	31.

Note: Figures refer to concentrations of P_2O_5 in the solutions. Ratio soil to phosphate solution=1:10.

Referring to the table we note in the case of the high fixing soil (5448) that applications of phosphate as large as 400 p. p. m. (equivalent to 10,000 pounds per acre) have resulted in but 1.5 p.p.m. of phosphate remaining in solution. In contrast, the low fixing soil absorbed slightly less than two-thirds of an equivalent treatment, the quantity of phosphate thus remaining unfixed being equal to 3,700 pounds. Reference to the figure shows that an application of 2,500 pounds of P_2O_5 to the one soil results in more phosphate remaining unfixed than does five times that quantity, or 12,500 pounds, to the other.

Correlations With Field Observations

In order that a measure of the fixing power of a soil be of practical value to the plantation it is essential that the chemical data be interpretable in terms of crop

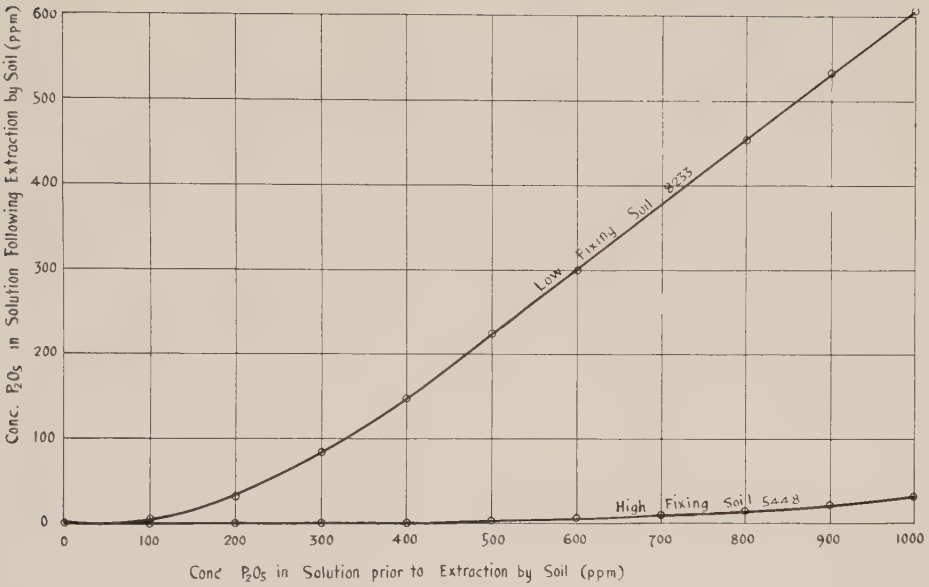

Fig. 3. Showing the quantities of phosphate remaining unfixed by a "high" and a "low" fixing soil following treatment with various amounts of phosphate. One hundred p.p.m. is the equivalent of 2500 pounds P_2O_5 per acre-foot of soil. (Period of extraction= 6 hours.)

response to phosphate fertilization. While field observations are lacking relative to many of the soils included in this study it will be seen, from the following correlation, that the degree to which these soils absorb phosphates, as shown by chemical test, may generally be taken as being roughly indicative of the availability to the crop of soluble phosphates applied thereon.

Reference to Table II shows the soils of the Waipio Substation to be the lowest in fixing power of any encountered in this study. A well-conducted fertilizer experiment harvested in this area in 1933 gave no indication that the added phosphate was not entirely available for utilization by the crop. Manifesting slightly greater absorption than these soils is a specimen from the island of Maui which has been extensively studied both in the laboratory and in the field. This phosphate-deficient soil has been conclusively shown to possess little, if any, ability to withhold added phosphate from the crop. Next in order, and covering a rather wide fixation range, are the soils of lower elevation on the island of Kauai. Upon a few of the higher fixing soils of this group it has been found profitable to employ soluble phosphates in excess of amounts assimilable by the crop. Generally speaking, however, there appears little reason to believe that soluble phosphates applied to these soils are not in large part available to the current cane crop. Table II shows the upland soils of Kauai to be capable of greater phosphate absorption than the lowland soils. Correspondingly, economic response to the higher treatments on the soils of that Island is most pronounced and most frequently met with in the regions of higher elevations. Isolated, with respect to their fixing power, from other Kauai soils are four infertile areas of high fixation. On only one of these have fertilizer tests been conducted. In this instance response was obtained to applications of soluble phos-

phates only when these exceeded 1,000 pounds P_2O_5 per acre. Soils of the Manoa Substation, according to our classification, exhibit fixing power comparable in extent to that of the less extreme Hilo Coast soils. Cane growing on these high-fixing Substation soils does not respond to fertilization with phosphate except in amounts equal to many times the requirements of the current crop. All of the Hilo Coast soils examined fixed above 96 per cent of the applied phosphate. This fact, viewed in the light of the foregoing discussion, might well lead us to expect, if we did not know otherwise, that normal cane crops could not be produced on the soils of the Hilo Coast region except through the use of great quantities of phosphate. Such, we know, is not the case. Manifestly then, there exists a fundamental difference between the soils of this region and the other widely selected specimens examined in the course of this study.

Conclusions

It is very probable that most, if not all, Hawaiian soils are capable of fixing upwards of several thousand pounds P_2O_5 per acre-foot under the laboratory conditions outlined in this paper. Nevertheless, we find the property of fixation to be far more pronounced in certain of our soils than in others, as is shown, for example, by a comparison of lowland Kauai with Hilo Coast soils. However, up to the point at which fixation begins to interfere with the absorption of phosphate by the plant roots, this property of the soil, far from being an objectionable characteristic, may be of decided benefit in holding the added phosphate against leaching action. Soils of the Waipio Substation appear to approximate this hypothetical group. Thus, while specimens from this district were found, by laboratory test, to possess considerable capacity to absorb phosphates, yet moderate quantities of the nutrient added to and doubtless fixed by this soil have been shown to be largely, if not wholly, available to the current cane crop. Beyond this point, however, fixation may present a problem. With the exception of the Hilo Coast soils the degree to which fixation occurs is roughly indicative of the availability to the crop of soluble phosphates applied in the field.

Our laboratory studies have shown that the smaller the quantity of soil with which a given amount of phosphate comes into contact the greater will be the period during which a part thereof will remain unfixed. We may conclude therefrom that concentrating soluble phosphatic fertilizer in the soil will result in less rapid fixation than would be the case were it more generally distributed. The success of such a scheme to combat fixation will depend largely upon the absorbing capacity of the relatively small number of roots penetrating this very limited zone of comparatively high phosphate concentration.

Where subsoils are higher in fixing power than corresponding surface soils, and where soluble phosphates are used, it is important to direct attention toward applying the phosphatic fertilizer in the lower fixing surface soil. The degree to which such a practice will prove beneficial will depend largely upon the depth of the surface soil and the proportion of the active roots contained therein.

Summary

(a) The development in this laboratory of a method for comparing the fixing capacities of soils is discussed in detail.

(b) Seventy-five surface soils, principally from the island of Kauai and the

Hilo Coast region of Hawaii, are classified according to their phosphate-fixing power.

(c) Of the soils thus far investigated, those possessing the least capacity to absorb phosphates were found at the Waipio Substation. Extreme fixation was shown to occur in the soils of the Hilo Coast.

(d) Lowland soils of the island of Kauai were shown to be lower in phosphate-fixing power than upland soils.

(e) The lowest fixing soils of the Kauai soils studied were found at the lower elevations on the dry, leeward side of the island.

(f) The extent to which fixation occurs was shown, in general, to characterize the soils of a given locality.

(g) Fixation was shown to be more severe in the subsoils of Kauai than in the corresponding surface soils.

(h) All the soils studied fixed upwards of several thousand pounds P_2O_5 per acre-foot under the conditions of the test.

(i) The rates of fixation by typical Hawaiian soil types were studied. When soils were treated with solutions of phosphate and subjected to continuous mechanical agitation, fixation was found to occur at a tremendous rate during the first hour. Subsequently it diminished, becoming very low and constant in about 12 hours and continuing thus for the balance of the 48-hour period during which the test was conducted.

(j) The higher fixing soils were found to absorb phosphates more rapidly than the lower fixing soils.

(k) The rate at which fixation occurs was found to depend upon the relative quantities of soil and phosphate reacting. This suggests that fixation under field conditions may be effectively retarded by applying the phosphate in limited zones accessible to the cane roots.

(l) Excepting the soils of the Hilo Coast, a general correlation was found to exist between the degree to which fixation occurs in soils and the availability therein of applied soluble phosphate.

The writer wishes to acknowledge the helpful suggestions, constructive criticisms and assistance in interpretation of data received from his associates—Dr. Hance, Mr. Borden and Mr. Davis. He also gratefully acknowledges the generous aid received in securing the material necessary for this work by members of plantation staffs, especially J. N. P. Webster, and by members of the Agricultural Department of this Experiment Station.

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Applying Mill By-products to Cane Fields—Costs and Comments*

By R. Bryan, J. C. Carter and M. J. Black

From a questionnaire sent to all plantations on Hawaii for data concerned with costs in connection with hauling and handling press cake, molasses, and mill ash in the fields, we have compiled the following information:

Press Cake

Hauling Cost:

Ten plantations report average hauling distances from 1½ to 6 miles; the average for the ten plantations being about 3½ miles.

Nine plantations report hauling press cake by trucks at a cost ranging from $0.035 to $0.52 per ton mile; the average being about $0.22 per ton mile.

Three plantations report hauling press cake by railroad at a cost ranging from $0.03 to $0.09 per ton mile.

Four plantations report hauling press cake by pack animals at a cost ranging from $0.12 to $0.63 per ton mile.

One plantation reports hauling press cake by hoists at a cost of $0.20 per ton mile.

Cost of Applying and Amounts Applied:

One plantation reports a cost of $0.47 per ton for applying 21.5 tons per acre, using sleds.

Two plantations report using irrigation water as a means of applying press cake; the cost at one being $0.10 per ton for a 20-ton application, and at the other $0.15 per ton for an 11-ton application.

Four plantations report using pack animals for distributing press cake in the fields, $0.40 per ton for a 20-ton-per-acre application, $0.12 per ton for a 10-ton application, $1.25 per ton for a 17-ton application, and $0.10 per ton for a 40-ton application.

For costs on bagging and applying we find six plantations reporting costs ranging from $0.05 to $1.00 per ton, with the tons applied per acre ranging from 10 to 40 tons.

Two plantations report fluming press cake on unirrigated lands; $0.06 per ton to apply 18 tons per acre, and $0.27 per ton to apply 30 tons per acre are their respective costs.

In answer to "Have you at any time observed a residual effect from applications of press cake?" we have three plantations answering "No," five answering "Yes," one "Occasionally," and one "No observations." Two of the plantations answering "Yes" state the effect lasts for three crops.

* A report of a committee selected to study this question and presented at the 1934 group meeting of field men and others on the Island of Hawaii.

In answer to the question, "Is the amount of commercial fertilizer reduced on areas where press cake has been applied?" we find nine plantations answering "No," two "Yes," and one "Occasionally." Five of the plantations answering "No" state that the press cake is applied on poor areas only.

We would like to quote some of the remarks taken from the questionnaires:

Paauhau Sugar Plantation Company: We believe that measurable results from applications of press cake cannot be readily obtained.

Onomea Sugar Company: Plant cane without press cake in the furrows is slower in starting. Mud press gives the young roots plant food immediately.

Olaa Sugar Company: Before the installation of the Oliver filters and when using the old presses, the sucrose in the mud ran about 3 per cent. Our recovery with the Oliver filters is about .3 per cent and it was noted that the same results were not being obtained in the fields from applications of mud press. By adding molasses at the rate of approximately one to three, the sucrose content has been brought back to more than it was before and a good response is again evidenced in the field.

Laupahoehoe Sugar Company: We have found mud press to be beneficial; particularly in improving the fertility of poor spots in the fields.

Waiakea Mill Company: Heavy applications of mud press causes a deleterious effect on the juice.

Hakalau Plantation Company: In our fields in particular, the cane tonnage dropped when we reduced the fertilizer application on areas which had received press cake.

Hutchinson Sugar Plantation Company: We generally apply press cake on the knolls and poor spots in the fields.

Honomu Sugar Company: Press cake appears to be particularly beneficial to the middle belt fields.

The Honomu Sugar Company submits the following interesting cost figures on applying a mixture of press cake and molasses. The mixture is hauled by trucks to the fields, sledded to various parts of the fields and spread by hand, with the exception of Field 36B, which was flumed:

TOTAL MUD-PRESS CAKE MIXED WITH 18 PER CENT MOLASSES MADE AND DELIVERED TO FIELDS FROM JANUARY, 1933, TO SEPTEMBER, 1933

Field No.	Tons Press Cake	Tons Molasses	Total Tons	Total Cost	Cost per Ton	Acres Appl.	Cost per Acre	Haul Distance, Miles
4.....	117.42	25.78	143.20	$ 146.49	$1.023	15	$ 9.77	3
6-A.....	512.42	112.48	624.90	566.35	.906	55	10.30	3
23-A.....	223.04	48.96	272.00	162.17	.596	25	6.49	2½
25-A.....	160.15	35.15	195.30	125.29	.641	18	6.96	3
25-B.....	291.92	64.08	356.00	329.90	.927	40	8.25	3
32.....	40.67	8.93	49.60	44.83	.904	5	8.97	1
37.....	285.61	62.69	348.30	301.62	.866	32	9.43	3
Total....	1631.23	358.07	1989.30	$1676.65	$ .842	190	$ 8.82	
Flumed 36-B...	271.17	59.53	330.70	239.13	.723	22	10.87	3½
Grand Total...	1902.40	417.60	2320.00	$1915.78	$ .826	212	$ 9.04	

This mixture contains by analysis:
0.56% N, 0.96% P_2O_5, 0.23% K_2O, 1.30% CaO.

The Onomea Sugar Company submits the following costs on applying press cake with a mechanical spreader hauled by tractor. The cake is hauled to the

fields in dump trucks, and a movable ramp facilitates dumping the loads directly into the spreader:

Onomea Sugar Company, Field 80, applied April, 1933:		
Two dump trucks, labor (2 men and superintendence)	$5.16	
Tires per day	1.00	
Tax	.40	
Gasoline, oil and grease for 2 trucks per day	3.40	
Estimated repairs to trucks per day	1.50	$11.46
Tractor operator and superintendence	$1.58	
Mechanical spreader	1.08	
Gasoline, oil and grease for tractor per day	7.00	
Repairs to tractor per day	.75	10.41
Five men and superintendence loading bin		5.40
Total cost hauling and spreading		$27.27
Forty-four loads of mud press per day equal		77 tons
Seventy-seven tons of mud press, 10 tons per acre, cover		7.7 acres
Cost per ton mud press		$ .354
Cost per acre		$3.54
Distance mud press hauled—mill to field		1 mile

The Paauhau Sugar Plantation Company reports:

During 1928 we composted about 1833 tons of molashcake. By analysis this contained .7 per cent N, 1.1 per cent P_2O_5, .9 per cent K_2O, and 1.8 per cent CaO. Cost per ton for composting and spreading, without considering overhead on labor and repairs or depreciation on equipment was:

Composting	$1.16 per ton
Spreading	1.37 " "
Total	$2.53 " "

Molasses

Very little information is available on costs of transporting and applying molasses.

One plantation reports a cost of $0.27 per ton mile, hauling molasses by trucks. Two plantations report costs of $0.03 and $0.05 per ton mile hauling by railroad. One plantation reports a cost of $0.10 per ton mile hauling by hoists. One plantation reports an application cost of $0.10 per ton for a 5-ton application in irrigation water.

We are fortunate in being able to present costs on the applying of 306 tons of molasses recently at Hamakua Mill Company. The molasses was hauled by a "75" tractor in a large tank wagon of the crawler type equipped with a pipe spreader; all of the hauling was up steep grades. When we consider the amount of potash applied per acre, the costs do not appear prohibitive. This method of applying molasses to unirrigated areas is deserving of further attention.

Hamakua Mill Company, Field 12, Paauilo: A Diesel "75" was used for the hauling.

Average number of trips per day	2.13
Length of haul—one way, miles	1.50
Average tons of molasses per trip	6.25
Average tons molasses applied per acre	4.71
Per cent K_2O in Hamakua Mill Company molasses	3.24
Pounds K_2O applied per acre	305
Average cost of applying per acre	$ 2.13
Average cost of applying per ton	$ .45

These averages were drawn from the following figures: 306 tons of molasses applied to 65 acres over a total of 23 days. The equipment required a driver and helper.

Minimum Requirements for Bundle Weighing and Taring in Grade "A" Field Experiments*

By R. J. Borden, W. C. Jennings and H. L. Weber

Bundle Weights

Previous Studies:

A review of the data concerned with bundle weights was made with a view of securing a good idea of the variations that had been encountered, and the possible error that might be introduced into plot cane yields when only every third or fifth bundle was weighed.

(1) From a study in 1916 by W. P. Alexander on 13 plots at Pepeekeo Sugar Company, we note:

	Tons Difference: Every Bundle vs. Every Third Bundle	Per Cent Diff.	Tons Difference: Every Bundle vs. Every Fifth Bundle	Per Cent Diff.
Maximum error for plot	.39 ton	3.2	.90 ton	7.5
Minimum error for plot	.09 "	.9	.12 "	1.3
Average error for plot	.21 "	2.02	.31 "	2.99

Average bundle weight—53.7 lbs.
Average number of bundles per plot—386.
Every third bundle means that approximately 125 bundles were weighed.
Every fifth bundle means that approximately 75 bundles were weighed.

(2) From a study in 1919 by Y. Kutsunai from 24 "X" plots of Experiment 4 at Onomea Sugar Company:

	Tons Difference: Every Bundle vs. Every Third Bundle	Per Cent Diff.	Tons Difference: Every Bundle vs. Every Fifth Bundle	Per Cent Diff.
Maximum error for plot	.136 ton	3.5	.24 ton	5.3
Minimum error for plot	.006 "	.1	.008 "	.2
Average error for plot	.054 "	1.2	.07 "	1.7

Average bundle weight—54.5 lbs.
Average number of bundles per plot—171.
Every third bundle means that approximately 57 bundles were weighed.
Every fifth bundle means that approximately 34 bundles were weighed.

(3) From a study (about 1920) by T. E. Merriam—40 plots:

	Every Third Bundle	Every Fifth Bundle
Largest error	3.9 %	4.8 %
Smallest error	0	.1 "
Average error	1.06 "	1.72 "

* A report of a committee selected to study this question and to make recommendations concerning it to the 1931 group meeting of field men and others on the Island of Hawaii.

(4) From a study in 1922 by Y. Kutsunai at the Hilo Sugar Company:

No. of Bundles	Probable Maximum Error
5	6.6%
10	4.5"
20	3.1"
30	2.6"
40	2.2"
50	2.0"
60	1.8"

Mr. Kutsunai comments that "at least 30 bundles must be weighed to get an accuracy within 3 per cent."

(5) Studies made in 1929 by R. J. Borden from Honokaa and Hilo Sugar Company bundle weights showed that departures from the true average weight were seldom greater than 2 pounds per bundle when only every third bundle was weighed. This was equivalent to an error of approximately 2½ per cent. Every third bundle meant that from 33 to 55 bundles were weighed in these studies.

(6) L. S. McLane in 1931 studied bundle weights from 14 plots at Honomu Sugar Company and found that the greatest plot yield difference as calculated from every bundle and from every third bundle was only .8 per cent. He concluded that "every third bundle is sufficiently accurate in experimental plots at Honomu." Approximately 50 bundles per plot were weighed.

(7) In 1930, R. K. Conant studied a large number of bundle weights at Olaa Sugar Company and concluded that "yields obtained by weighing every third or every fifth bundle in plots of 1/20 acre, differed from yields obtained by weighing all bundles per plot sufficiently to contend that where large variation of weights between bundles exists, it is necessary to weigh all bundles to insure accuracy."

Recent Studies:

We have recently made three statistical studies of bundle weights with results as follows:

Source	No. of Bundles	Av. Wt. Lbs.	Standard Deviation Lbs.	Coefficient of Variation Per Cent	Approximate Theoretically Possible Deviation from Actual Bundle Weight for Average of 36 Bundles	49 Bundles
1. Olaa "Y" plots..	280	76	14.5	19.0	5 lbs.	4 lbs.
2. Hilo—1929	200	80	8.2	10.2	3 "	2½ "
3. Pepeekeo—1933...	940	87	8.0	9.2	3 "	2½ "

These wide differences in variation indicate the variable nature of individual cane bundle weights, and show how necessary it is for us to secure an average bundle weight from a considerable number of bundles if our plot yield is to be accurately determined from such data.

Bundle Tares

Much less tare data were available for study, but those available were subjected to a statistical study with results as follows:

Source	No. of Tares	Average Tare	Standard Deviation	Coefficient of Variation
Olaa	828	5.5 lbs.	3.1 lbs.	56.3%
Pepeekeo	2023	8.13 "	2.67 "	32.8"
Honokaa No. 1.....	20	16.5 "	4.0 "	24.2"
Honokaa No. 2.....	20	19.7 "	9.8 "	49.7"
Onomea No. 8.....	12	5.2 "	1.7 "	32.7"

Here likewise we note extreme variability in the weights of bundle tares.

The data furnished several years ago by Mr. Conant from Olaa Sugar Company, Experiment 30-2, offered interesting evidence of significant differences between the average tares for different treatments, as well as between different plots of the same treatment. Thus we feel that separate tares must be determined for each plot of each treatment.

We believe, however, that there is no point in securing a greater degree of accuracy in tare figures than that which we can secure in bundle weights, and vice versa. Thus we are now led to present two tables: one that gives the standard errors for the means of 10, 20, 30, 40, 50 and 100 bundle weights, set down opposite varying degrees of standard deviation, and another that gives a corresponding scale of standard errors for the means of 2, 3, 4, 5, 6, 8 and 10 tares as set opposite a range of standard deviation figures for tares.

TABLE 1. STANDARD ERRORS OF THE MEAN BUNDLE WEIGHT (Pounds)

Standard Deviation of a Single Bundle Weight	Bundles					
	10	20	30	40	50	100
6	1.90	1.34	1.10	.95	.85	.60
7	2.21	1.57	1.28	1.11	.99	.70
8	2.53	1.79	1.46	1.26	1.13	.80
9	2.85	2.01	1.64	1.42	1.27	.90
10	3.16	2.24	1.83	1.58	1.41	1.00
15	4.74	3.35	2.74	2.37	2.12	1.50

TABLE 2. STANDARD ERRORS OF THE MEAN TARE (Pounds)

Standard Deviation of a Single Tare	Tares						
	2	3	4	5	6	8	10
2	1.41	1.15	1.00	.89	.82	.71	.63
3	2.12	1.73	1.50	1.34	1.22	1.06	.95
4	2.83	2.31	2.00	1.79	1.63	1.41	1.26
5	3.54	2.89	2.50	2.24	2.04	1.77	1.58

From these two tables one may choose a number of tares that will give comparable accuracy with the number of bundle weights averaged, after he has estimated or determined the average variations (standard deviations) for his usual bundle and tare weights. For example: if we assume the standard deviation for bundle weights at 8 pounds and for tares at 3 pounds, we can obtain approximately the same degree of accuracy in both weights from weighing (a) 30 bundles (standard error 1.46 pounds) and from 4 tares (standard error 1.50 pounds); (b) with 40 bundle weights and 6 tares, etc.

Because these standard deviations are so differently affected by location, cutter, character of burn, variety, treatment, etc., it is difficult to justify a recommendation for any definite number of bundle weights and tares for Grade "A" experiments. Realizing, however, that it is desirable to set a definite minimum qualification, we would recommend that not less than 40 bundles be weighed per plot (unless the total number of bundles in the plot is less than 40, in which case all should be weighed), and not less than 6 tares per plot (2 tares per cutter) be taken, in order to secure the net cane yield from which the plot tons cane per acre will be calculated. These 40 bundles should be taken in such a way that they reliably represent all the cane grown on the plot.

"A Correction for the Juice Sampling Error That is Due to Water in Field Trash"*

By H. F. Hadfield

At the last meeting of this group, held during January, 1933, a report was read, based on the fact that whenever flumed cane was accompanied with large amounts of field trash over a cane carrier, especially if the carrier is of the steel slat type, the field trash absorbed, and also carried over with it, large quantities of flume water into the first expressed juice, thus reducing the density, and causing an "Error" which required correcting; otherwise the quality ratio, or the calculated tons of cane would be higher than it should be.

Your Committee has conducted several experiments with a view of finding some "Factor" in order to correct this error, with the following results: In reality the factor advocated by your committee is not an absolute juice factor, but nevertheless of infinite value, and may be used as such. The real absolute juice factor may be determined by means of a dry crushing test, which includes the juice extraction per cent cane, the Brix of each mill, as well as the purity of the last mill juice, and the pol of the last mill bagasse, which is not included in the factor advocated by your committee.

This official method of determining the absolute juice factor seems, however, to be too low, as the following tests show:

Dry crushing tests for absolute juice factor....	99.19
	100.06
	97.41
	100.40

To an observer watching the cane entering the crusher it is obvious that quantities of water are being carried over into the first expressed juice. The absolute juice factor should therefore be above 100. Subsequent tests prove this to be the case, and the above method does not seem to account for this error of water entering the first expressed juice.

Experiment 1

The first experiment was based upon a suggestion that the Brix of the juice from the bagasse roll of the first mill, which has not been diluted with maceration, be regarded as the Brix of the absolute juice.

Under these conditions it was expected that the Brix of this juice would be higher than that of the crusher, for the crusher juice was already diluted with flume water.

* A report of a committee selected to study this question and to make recommendations to the 1934 group meeting of field men and others on the Island of Hawaii.

The following eighty-nine samples were therefore taken:

10	samples	crusher	Brix	14.75	Samples	bag.	roll	1st	mill	Brix	14.63
8	"	"	"	15.83	"	"	"	"	"	"	15.56
10	"	"	"	14.68	"	"	"	"	"	"	14.19
9	"	"	"	15.68	"	"	"	"	"	"	14.73
20	"	"	"	15.59	"	"	"	"	"	"	15.28
12	"	"	"	15.56	"	"	"	"	"	"	15.14
20	"	"	"	15.32	"	"	"	"	"	"	14.73

The average being 15.36 for crusher samples, and 14.91 for the bagasse roll of the first mill.

These tests seem to show that this method is not of much value, as the Brix of the eighty-nine samples of the crusher juice was higher than that of the bagasse roll juice of the first mill. Sometimes, however, the reverse of this is true.

Walter E. Smith comments on this method as follows:

These tests comparing crusher juice with first bagasse roll juice can only be accounted for on the basis that the light pressure of the crusher is not sufficient to express any appreciable amount of this water out of the wet trash, and that a large part is therefore expressed later by the bagasse roll of the first mill.

How else could you account for the lower Brix of the first mill bagasse roll juice? And if this is so, does it follow that the crusher sample is being materially diluted, or rather, more so than the first mill juice?

Experiment 2.

The second experiment was based upon the fact that, provided flume water was carried over into the juice by the field trash only, i. e., by absorption, and the rest of it was drained off the steel slat carrier, it was possible to estimate the amount absorbed by the field trash, and thus possibly correct the error by calculations. Twenty-four samples of cane with their accompanying trash were therefore taken from the flumes as they travelled from the field to the cane carrier, and the wet field trash was weighed, including cane tops, leaves, and borer-eaten cane.

These samples of field trash were then sun dried, and weighed again; the following are the results:

Water of absorption, 55.00, 50.29, 69.08, 72.40, 72.22, 58.38, 77.31, 71.93, 63.44, 65.58, 63.72, 71.91, 63.47, 75.00, 61.24, 75.70, 46.30, 56.51, 38.40, 39.00, 78.00, 71.59, 43.89, 52.90.

An *average* of 61.22 per cent water absorbed by field trash.

Mr. Smith comments on this method as follows:

If we assume that the field trash is carrying into the mill certain amounts of water, this water will not be entirely expressed into the crusher juice unless the wet field trash is reduced to the same moisture content as that found for this field trash after it has been sun dried.

It would appear quite unlikely that this is the case, as material leaving the crusher is quite obviously wetter than sun dried field trash. Furthermore, the amount of water actually expressed will vary with the quality of the crusher work, being more when the crusher is well loaded, and less with a light load and low crushing performance.

Hence, it would appear difficult to assume that the amount of dilution of the crusher juice was actually equal to the amount of water of absorption carried into the mill by the field trash.

The more I puzzle over this problem, the more hopeless it appears to me to arrive at any relatively simple method of estimating the effect of the water of absorption, and should hesitate to say specifically that this method would give a very positive way of correcting for water.

Experiment 3.

The third, and final, experiment is based upon the fact that where a sample of uncleaned, wet cane is flumed over a cane carrier, especially if the carrier is of the steel slat type, the Brix of the first expressed juice crushed from this cane is lower than the Brix of the juice from the same sample of cane when it is dry and cleaned of all field trash.

Four varieties of cane were subjected to this test as follows:

	Brix	Pol	Pur.	Q. R.	Juice Factor	% Field Trash	% Dil.
Yellow Caledonia							
Cleaned cane	17.42	15.60	89.55	8.40	.....	None	.....
Uncleaned cane	16.02	14.13	88.20	9.44	108.74	8.85	8.03
D 1135							
Cleaned cane	16.26	14.59	89.73	9.00	.....	None	.....
Uncleaned cane	13.56	11.99	88.42	11.00	119.91	12.16	16.61
P. O. J. 36							
Cleaned cane	15.86	14.22	89.66	9.20	.....	None	.....
Uncleaned cane	13.66	11.97	87.63	11.10	116.11	14.90	13.87
P. O. J. 213							
Cleaned cane	16.62	15.26	91.82	8.45	.....	None	.....
Uncleaned cane.....	13.49	11.89	88.14	11.20	123.20	12.50	18.83

In the above data, it will be seen that: The Brix and purity of the juice from the cleaned cane is higher than that of the uncleaned cane; also the quality ratio is lower in case of the cleaned cane; and in order to correct the error for the dilution, a juice factor from 108.74 to 123.20 must be used; the field trash varied from 8.85 to 14.90, and the dilution from 8.03 to 18.83 per cent.

Mr. Smith comments on this method as follows:

In this experiment showing the effect of field trash and its accompanying water, the percentage of field trash in all cases is rather high, 8.8 per cent, 12.16 per cent, 14.9 per cent and 12.5 per cent.

In these instances the dilution effect is quite high—but in the final analysis, is it not apparent that such high field trash figures are very undesirable, and that they represent an abnormal condition which should be corrected from other standpoints?

In these tests the juice purity is depressed from 1.3 to 2.0 points by the field trash. While in all cases the introduction of the field trash has also introduced water, which dilutes the juices, it is obvious that some non-sugars must also have been introduced to reduce the purity. Obviously no sucrose is added, so that from an initial ton of sucrose in juice, to depress the purity two points, we must also introduce 45 pounds of non-sugar solids.

At about 33 purity of waste molasses, this means a loss of 15 pounds of sucrose per ton of sucrose in juice; an item, of course, of considerable importance.

It does seem, therefore, that by making a series of tests as outlined under the Experiment 3 method, it might be possible to obtain a series of factors to apply for different

varieties and various amounts of field trash. These could at best be only approximate, but might be better than our present methods.

In conclusion, your Committee suggests that out of the three tentative methods suggested, Experiment 3 may be used in determining a factor for correcting the error in the density of the first expressed juice, due to fluming water being carried over a cane carrier into the first expressed juice.

On Setting the Crest Elevation for the Parshall Flume

By H. A. Wadsworth

The increasing local interest in the Parshall Flume as a means of measuring irrigation water has prompted a brief study of the conditions governing the most desirable elevation of the crest under field conditions. In ditches on flat grades this elevation is most critical. If too low the structure will become submerged thus requiring two gage readings in place of one, as well as troublesome arithmetical manipulations after the readings are secured. If set too high the water in the ditch will back up, increasing water losses and possibly endangering the ditch banks. The purpose of this note is to outline a procedure by which the proper elevation may be determined before the construction of the device is begun. Relocating a flume to avoid either of these difficulties may double its cost.

In its most comprehensive form the Parshall Flume is equipped with two gages. One of these is in the intake section, the point of measurement being one-third of the distance from the intake to the throat. The depth of water above the level floor of the intake section at the upper gage is called H_a and is the gage height given for varying discharges in the standard free-flow tables. The other measuring station, not often provided for particularly in local installation, is at the downstream end of the throat, the opening into the stilling well being three inches above the bottom of the depression in the floor and two inches upstream. Gage heights in this well are measured on a gage or rule set with its zero reading on the plane of the floor produced. This gage reading is known as H_b. The locations of these gages and their datum plane are shown in the figure.

It was soon found that in most installations the gage reading at H_b was unnecessary since H_a was a direct function of the discharge. This aspect of the flume's performance is called "free-flow." Most, if not all, the flumes in the Islands enjoy free-flow conditions; consequently only one gage is necessary and only one provided.

Under unsatisfactory conditions of installation the stream fails to get away from the structure fast enough to permit this desirable condition. In such cases the water in the diverging section may be crowded back into the throat section, producing what is known as a "standing wave" or "hydraulic jump." When the water in the stilling well at H_b has risen to "zero" on gage H_b, the structure is said to be submerged but the degree of submergence is zero and no harm is done. Increased obstruction in the get-away causes an increase in H_b and the degree of submergence increases. The magnitude of submergence is measured by dividing the head at H_b by H_a. This fraction is expressed as a per cent. As an example, if H_a equals 1.70 feet and H_b equals 0.92 foot the submergence is said to be 54 per cent.

One of the virtues of the Parshall Flume is that the gage reading at H_a is a direct measure of the discharge until the percentage of submergence becomes 70 per cent for flumes of ordinary size. Further increase in H_b is reflected in an increase in H_a, although there may be no increase in discharge. Consequently,

the discharge secured by using the table in the usual way in such cases is greater than the true discharge by an amount which is a function of the degree of submergence.

Although the quantity to be subtracted from the tabular discharge can be computed with fair precision if the degree of submergence is known, the operation is time consuming. Moreover two water-stage registers would be required for a continuous record of the discharge performance of any flume experiencing a greater degree of submergence than 70 per cent.

Consequently, local flumes are ordinarily set high enough that this maximum tolerable submergence will not be exceeded.

The proper elevation of the floor of the flume depends upon:

(1) The maximum amount of water to be measured.
(2) The depth of water in the ditch when this quantity of water is being delivered.
(3) The size of the flume.
(4) The loss of head resulting from any particular combination of discharge and flume size.
(5) The permissible degree of submergence for free-flow conditions in view of the size of flume used. As indicated this may be taken as 70 per cent except for flumes with a width of less than one foot.

"Cut and try" methods can best be used in deciding on the crest elevation for certain conditions. Suppose a ditch carries a maximum flow of 8.5 M.G.D. or, say, 13 c.f.s. and that the depth of water in the ditch at the proposed point of installation is 2.0 feet when this quantity is being delivered; the problem lies in establishing the elevation of the crest somewhere within this 2.0-foot range so that

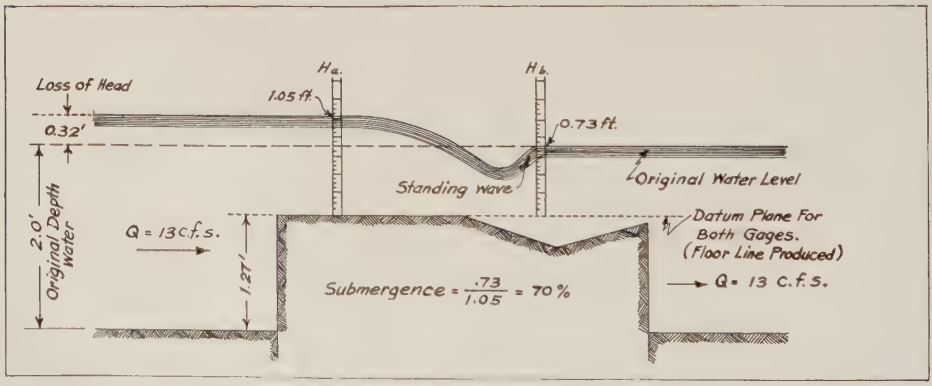


Fig. 1. Diagrammatic sketch of a three-foot Parshall flume carrying 13 c.f.s. Note relative position of gages.

the water level in the ditch below the device may keep its normal position and still allow free-flow conditions. It is hydraulically impossible to install a flume without the water standing at a higher elevation above the flume than it did originally. This difference is called the "loss of head" and on flat grades must be kept at a minimum.

At least four flume widths suggest themselves upon consulting the discharge tables. One of these is the three-foot flume. If this flume be used, H_a would

be 1.05 feet. Since a submergence of 70 per cent is permissible, it is evident that the gage reading at H_b may be (1.05 x 0.70) or 0.73 foot without violating free-flow conditions. Since both gages stand on the same datum plane, the loss of head due to the structure would be (1.05-0.73) or 0.32 foot. Since the depth of water in the ditch below the device must be 2.00 feet according to the assumption, it follows that the depth of water above the device at maximum discharge would be 2.32 feet in view of the head lost at this flow. The reading of head at H_a is the distance between the floor of the flume and the upstream water level. Consequently, since $H_a = 1.05$ the floor should be set 1.27 feet (or 2.32 minus 1.05) above the bottom of the ditch.

In tabular form these data and those for other flume sizes appear as follows:

Flume Size in Feet	Q	H_a	H_b*	Maximum Loss of Head	Necessary Upstream Depth	Elevation of Floor Above Ditch Bottom†
3.0	13.0	1.05	0.73	0.32	2.32	1.27
4.0	13.0	0.88	0.62	0.26	2.26	1.38
5.0	13.0	0.76	0.53	0.23	2.23	1.46
6.0	13.0	0.68	0.48	0.20	2.20	1.52

* Based on a permissible submergence of 70 per cent.
$H_b = H_a \times 0.70$.

† Difference between necessary upstream depth and H_a.

These relations for the three-foot flume are shown in the figure.

With such a table available one is able to consider the other factors which may affect the installation. For flows which are essentially constant the use of the smallest flume would be most desirable, partly because of the economy of construction but also because of its increased sensitivity to minor variations of flow.

Some plantation ditches experience freshet flows in which the normal capacity is far exceeded. In such cases a larger flume than is normally required may be used or the side walls may be extended vertically to care for the excess head. According to Mr. Parshall the extrapolation of the discharge tables to include these occasional heads seems justified. Such extrapolations for the most frequently used flume sizes are available at the Experiment Station H.S.P.A. Regardless of the policy used with respect to flood-flow, the elevation of the crest may be determined by the procedure given above.

In general, plantation flumes are not submerged to the degree indicated. Mr. Parshall after exhaustive tests has concluded that free-flow conditions exist at 70 per cent submergence for all flumes of one foot or larger in size. For flumes smaller than one foot, the permissible submergence for free-flow is 60 per cent. Agriculturists who plan to use a maximum submergence of less than 70 per cent will naturally make the required modification of the form given in the table.

The Sugar Industry of Mauritius*

The island of Mauritius, of volcanic origin, athwart the southeast trade winds has a relief consisting of mountains, plateaus and coastal plains, and a rainfall heavy on the windward highlands and lighter on the leeward side. The island is occasionally visited by tropical cyclones.

Sugar cane culture, introduced into Mauritius in 1650, was considerably extended about 1744 when new strains were introduced. Between 1845 and 1863 impetus was given to the industry by the introduction and use of laborers from India. The period 1863 to 1895 was one of retrogression due to the successful competition of beet sugar which lowered the price, and to the occurrence of two calamitous cyclones. The industry recovered, a gradual increase in output due to improved methods of cultivation occurred, and in 1914 production reached a peak of 289,300 tons†, the record output for Mauritius. The year 1924 marked the beginning of a period of decline in the industry due to a fall in the price of sugar. The area used for the crop diminished and in some districts the Indians gave up the raising of sugar cane for market gardening.

More than forty varieties of sugar cane are raised on Mauritius. At the beginning of the twentieth century the three most common were the two Big-Tanna (white and striped), and MP55, the seed of which came from Penang. White Big-Tanna, the standard variety, has been attacked by disease, and P. O. J. 2878, a very hardy and disease-resistant strain from Java, has been introduced.

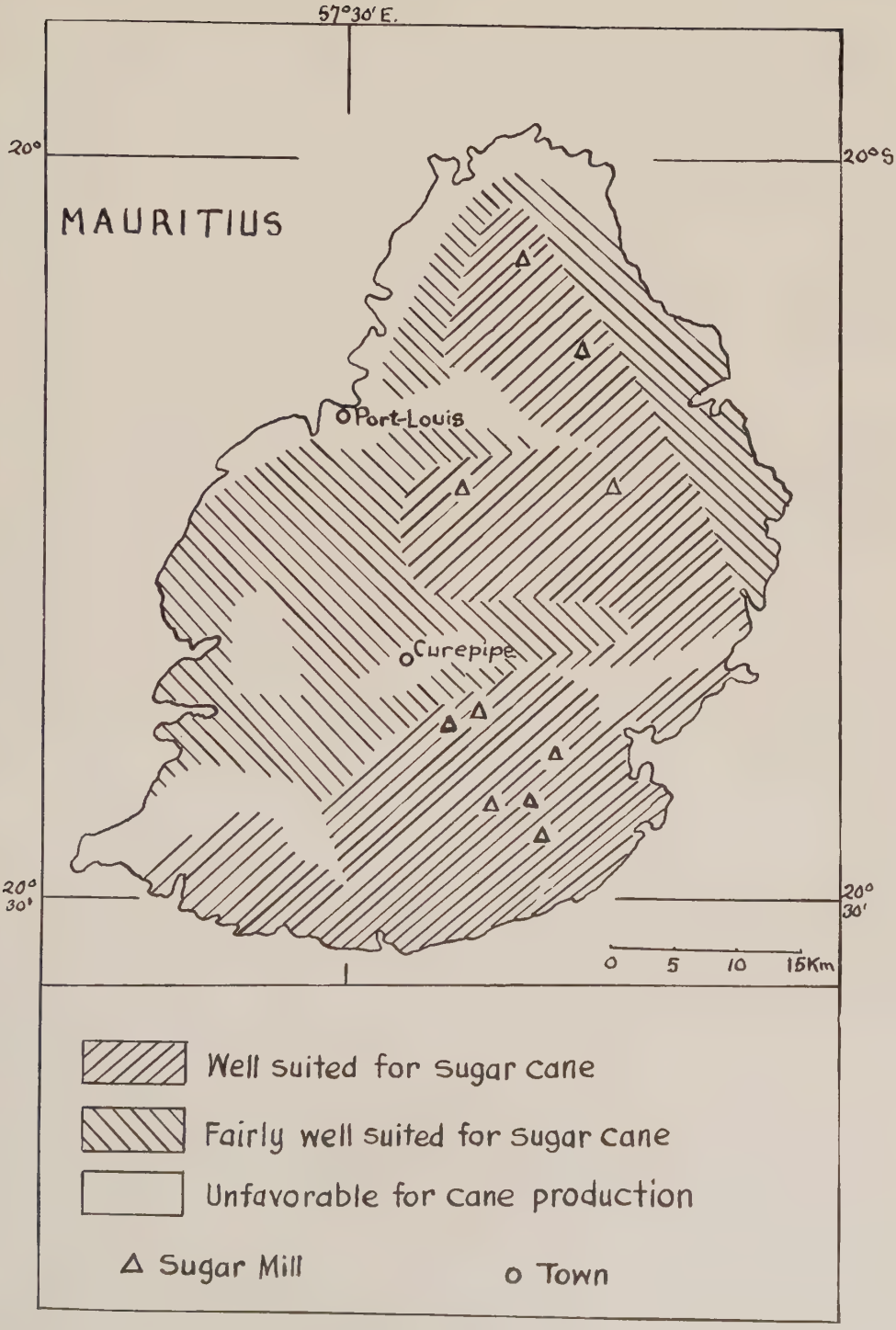
Antiquated agricultural methods in the industry have been given up for modern usages in which machinery and fertilizer play an important part. Four or five ratoon crops are harvested at intervals of twelve or thirteen months. Harvesting takes place in September, October, and November. Cut cane is carried from the fields to the mills on narrow-gauge railways. The average yield is 18 to 19 tons an acre. The yield is much greater on large plantations than on small farms, but the latter afford indisputable moral and social advantages to the proprietors, mostly Indians, and tend to increase.

In the early days of the sugar industry in Mauritius the extraction of sugar was distributed among many small mills, as many as 227 in 1854. With the development of better technique in milling their number gradually decreased and in 1925 only 47 were in operation. In 1925, twenty mills manufactured more than 5000 tons of sugar each and twenty-seven between 5000 and 2500 tons.

Most of the sugar companies own large plantations and grind their own cane and also that of small farmers. They also compete with one another in buying cane for their mills as a result of which there evolve delicate questions of relationships between big and small planters, especially since the mills with their improved

* The sugar industry on the island of Mauritius (about 20° S. lat. and 57° 30′ long.) is affected by conditions in many ways similar to those on the island of Oahu. This article is an abstract by J. W. Coulter (Dept. Geog., Univ. Hawaii) of an account of the sugar industry on Mauritius, by Paul Caubet, in *Annales de Geographie*, September, 1933, pp. 516-528.

† This seems to be long tons (2,240 pounds).


57°30' E.
20°
20° S
MAURITIUS
Port-Louis
Curepipe
20° 30'
20° 30'
0 5 10 15Km
Well suited for sugar cane
Fairly well suited for sugar cane
Unfavorable for cane production
Sugar Mill
Town

types of machinery can grind nearly twice as much sugar cane as is supplied to them. The average extraction of sugar is about 11 per cent by weight.

The distillation of rum from molasses, once a very important industry in Mauritius, has declined to very small proportions for the following reasons: (1) the closing of the market in Madagascar by a prohibitive duty, (2) an increase in freight rates to markets in London and eastern Africa, (3) an increase in the local excise duty, and (4) a rise in price of molasses.

Sugar makes up more than nine-tenths of the exports of Mauritius. India was formerly the principal market but now England takes four-fifths of the output allowing the island a preferential tariff. There have been great fluctuations in price. A low price at present coincides with an increase in cost of production as a consequence of which there is great uneasiness among producers.

The conclusion at which Caubet arrives from his study is that the production of sugar will remain the basic industry of Mauritius. Although the immediate post-war profits are not likely to obtain again, prices in the future will remain relatively stable. Improvements must be made in the agricultural aspects of the industry comparable with those in the mills. The subdivision of holdings for the benefit of immigrant Indians is bringing about a situation which involves in the future the solution of social problems just as important as economic phases of the industry.

Soil Terminology

Present-day interest in studying the soils of the individual fields of the plantation and adapting the fertilization to their special needs, brings about renewed interest in soil classification and soil terms that bear upon it.

At the First International Congress of Soil Science, which was held in Washington, D. C., during 1927, C. F. Shaw of the University of California, who was chairman of the Committee on Nomenclature of the American Soil Survey Association, presented a glossary of terms used in soil literature, using the following introduction when submitting his report:

Many of the terms now used in soil literature are given different meanings by writers in different countries and even by different authors within one country. This causes much confusion and it seems desirable to attempt to reach an agreement on definite interpretations of the terms in general use.

As chairman of the committee on Nomenclature of the American Soil Survey Association, the writer has compiled a glossary of terms used in soil classification and the soil survey. These terms and their definitions have been compiled from lists submitted by members of the Soil Survey Association and from a study of published soil surveys and papers dealing with soil classification. The definitions of the terms have been carefully phrased in an endeavor to express the meaning that has been established by general use and custom. Only a few terms that apply solely to the laboratory phases of soil science have been included; most of them apply to soil classification and the characteristics of the soil in the field.

It is not expected that all the definitions will be acceptable to all soil scientists, but it is hoped that most of the terms will be approved as defined and that those with debatable meanings will be discussed and a definite meaning for each term ultimately agreed upon.

General Terms

Soil: The soil is a natural body occupying the surface portion of the Earth, composed of mineral and organic materials and having more or less definitely developed horizons of eluviation and illuviation.

This term soil, as defined, includes both the Solum and the upper portion of the parent material, the A, B and C horizons.

Solum: The weathered portion of the soil mass including the full depth to which eluviation and illuviation are in evidence. The A and B horizons.

Parent Material: The slightly altered or wholly unweathered material beneath the solum, similar to that from which the soil was formed. The C horizons.

Eluviation—Eluvial: A process of removal by percolating waters of material in solution or in suspension. Horizons from which material has been removed by eluviation.

Illuviation—Illuvial: A process of accumulation by deposition from percolating waters of material transported in solution or suspension. Horizons in which material has been deposited by illuviation.

Soil Fertility: The capacity of a soil for production under favorable conditions.

Soil Productiveness: The actual producing power of a soil under the normally existing conditions.

Soil Characteristics: Distinguishing qualities, properties or features that may serve to establish the character of a soil.

Organic Matter (of the Soil): The more or less decomposed material of the soil derived from organic sources, usually from plant remains.

The term organic matter covers such material in all stages of decay and is recommended as a better term than "humus", which though in general use, is indefinite and poorly defined.

Humus: A more or less stable stage in the decomposition of organic matter in the soil. The organic matter that can be extracted from a soil by dilute alkali after treatment with dilute hydrochloric acid.

This term is quite indefinite in application and also in an analytical sense. It is better to use the more general term "organic matter" when referring to the organic content of the soil.

Claypan: An horizon of accumulation or a stratum of stiff, compact and relatively impervious clay.

The claypan is not cemented, and if immersed in water can be worked to a soft mass. Its presence may interfere with water movement or root development as does a true hardpan. It is more difficult to overcome for whereas a hardpan can be shattered by explosive the claypan, after breaking by any means, will run together and reform as soon as thoroughly wetted. The distinction between the hardpan and the claypan is an important one in the soil classification.

Hardpan: An horizon of accumulation that has been thoroughly cemented to an indurated, rock-like layer that will not soften when wet.

The term "hardpan" is not properly applied to hard clay layers that are not cemented, nor to those layers that may seem indurated when dry but which soften and lose their rock-like character when soaked in water. The true hardpan is cemented by materials that are not readily soluble, and is a hard layer that definitely and permanently (in nature) limits downward movement of roots and water.

Soil Genesis

Mineral Soils: Soils composed mainly of inorganic (mineral) material with relatively low contents of organic material.

Organic Soils: Soils composed mainly of organic material; the organic content being sufficient to dominate the soil characteristics.

Sedentary Soil: Soils formed in place without the addition of transported material.

Residual Soil: Sedentary soils formed by the weathering of mineral material.

Cumulose Soil: Sedentary soils formed by the accumulation of more or less decayed organic remains. Organic soils.

Peat Soil: Soil composed predominantly of organic material, considerably decomposed but highly fibrous, with easily recognizable plant remains.

Muck Soil: Soil composed of thoroughly decomposed organic material, with a considerable amount of mineral soil material, finely divided and with few fibrous remains.

Primary Soils: Soils developed through the disintegration and decomposition of rocks in place and the weathering of the resulting debris to true soils with definite horizons of eluviation and illuviation. Residual soils.

Secondary Soils: Soils developed through the weathering of materials, originating from previously existing soils and from rock debris, that have been eroded from their former locations and redeposited by the transporting agents. Transported soils.

Transported Soils: Soils formed by the consequent or subsequent weathering of materials transported and deposited by some agency such as water, air, ice, etc. Secondary soils.

Alluvial Soil: Soil formed from materials transported by flowing waters and deposited as alluvial fans and flood plains.

Marine Soil: Soil formed from materials deposited by the waters of oceans and seas, exposed by elevation of the land or the desiccation of the sea.

They are usually characterized by the commingling of sediments of different sizes that are not found in the deposits of any other agency except glaciation.

Aeolian Soil: Soil formed from materials transported and deposited by air.

This group includes not only the areas of wind-blown sand usually associated with sand dunes, but also the large areas of fine textured materials that have been wind deposited or wind modified since deposition, such as the wind modified deposits of fine volcanic ash, etc.

Soil Profile

Profile—Soil Profile: A Soil Profile is a vertical section of the soil from the surface to the underlying unweathered material.

Normal Profile: A characteristic profile developed under relatively uniform conditions of weathering.

Abnormal Profile: A profile departing from the Normal Profile conditions in some important respects, by reason of some unusual change in the factors governing weathering.

Abnormal profiles might be caused by excessive erosion following the removal of vegetative cover by fires, by changes in drainage conditions due to natural or artificial causes, or by any action which might change the natural conditions governing weathering.

Color Profile: A profile divided into horizons on the basis of color.

Chemical Profile: A profile divided into horizons on the basis of chemical composition.

Structural Profile: A profile divided into horizons on the basis of structure.

Textural Profile: A profile divided into horizons on the basis of texture.

Horizon—Soil Horizon: A layer or section of the soil profile, more or less well defined, and occupying a position approximately parallel to the soil surface.

Stratum—Strata: A layer or layers of material whose character was established during formation and is not due to subsequent alteration by weathering.

In transported soils there may be layers or strata of sand, clay, gravel, or other textures, of varying conditions with respect to structure and consistence, that may have an important bearing on the character of the soil, even influencing the effects of weathering agents. Hence in these definitions reference is made both to horizons and strata.

Horizon A: The upper horizon of the soil mass, from which material has been removed by percolating waters. The horizon of eluviation. The "surface" soil.

This horizon is generally subdivided into two or more sub-horizons, of which A_0 is not a part of the mineral soil, but is the accumulation of organic debris upon the soil surface. Other sub-horizons are designated as A_1, A_2, etc.

Horizon B: The horizon of deposition, to which materials have been added by percolating waters. The horizon of illuviation. The "subsoil."

This horizon may be divided into several sub-horizons, depending on the color, structure, consistence or the character of the material deposited. These sub-horizons are designated B_1, B_2, B_3, etc.

Horizon C: The horizon of relatively unweathered material underlying the B horizon. The "substratum."

The C horizon, while often described as "unweathered", usually shows some modification in the upper portions and may have one or more sub-horizons. In most cases it represents the "parent material" similar to that from which the soil was formed. In some cases it may be a stratum or geological formation of different material.

Surface Soil: The upper horizon or surface layer of the soil mass. The horizons above Horizon A_2.

In describing cultivated soils, it usually includes that portion that is modified by plowing and other tillage operations. In other cases, where the color of the upper portion of the soil mass is modified by accumulations of organic matter, it is applied to the full depth of that color horizon.

Subsurface Soil: The horizon or layer of soil directly beneath the surface soil. The A horizons below Horizon A_1.

In cases where the term "Surface Soil" is applied to the tilled portion of soils that are deep and uniform, it is used to include the portion of the uniform material below the tilled depth.

Subsoil: The horizons or layers of soil beneath the surface soils. The B horizons.

When necessary, the subdivisional terms upper subsoil, lower subsoil, etc., are used.

Substratum: The horizons or layers of material below the solum or true soil mass. The C horizons.

In most cases the substratum is the parent material. In some soils, it may be materials quite distinct in character from that which weathered to form the overlying soil mass. In

Recent soils, where distinct A and B horizons may not exist, it usually is applied to strata distinctly different in color, texture, structure or consistence from the upper or "soil" layers.

Soil Development

Recent Soil: A soil having a profile without definite horizons of eluviation or illuviation; relatively unweathered recent or very immature soil.

Recent soils usually are secondary soils composed of recently deposited transported materials, there being no evidence of any downward migration of clay, lime or other material, no evidence of differences in the degree of weathering of the minerals at any varying depths and no indication of any changes in structure of the soil.

Young Soil: A soil having a profile with slightly compact subsoil horizons, but without distinct clay accumulations; slightly weathered immature soil.

Immature Soil: A soil having a profile with compact subsoil horizons with distinct clay accumulations; moderately weathered immature soil.

Mature Soil: A soil having a profile with a compact highly colloidal dense clay horizon or with a cemented rock-like hardpan horizon; fully weathered mature soil. The end product of weathering under the existing conditions. A climax soil.

Soil Classification

Soil Type: A soil which throughout the full extent of its occurrence has relatively uniform texture of the surface soil and relatively uniform profile characteristics. The unit of soil mapping.

The name of the soil type is a combination of series name and the textural grade designation, as for example—Orangeburg sandy loam.

Phase: A subdivision of the "Soil Type" covering departures from the typical soil characteristics, insufficient to justify the establishment of a new type, yet worthy of recognition.

The phase subdivision is used when the deviation from the typical may be insufficient to warrant the establishment of a new type, or when the areal extent of a major variation is too small to warrant its independent recognition, yet where it is desirable to show the location and extent of the atypical material on the map and in the report. Phase variations may cover color, texture, structure, topography, drainage, or any other feature of deviation from the typical.

Soil Series: A group of soils having the same character of profile (the same range in color, structure, consistence, and the same sequence of horizons and degree of horizontal development), the same general conditions of relief and drainage and usually a common or similar origin and mode of formation. A group of soil types closely similar in all respects except the texture of the surface soils.

Soil Family: A group of soil series that are progressing toward a common or closely similar final mature profile condition.

The "Family" would include all soils regardless of their stage of development, that were progressing toward the same mature profile characteristics, and would indicate an existence, for different periods of time, under uniform and similar conditions of climate, vegetative cover and drainage. It might also indicate a common origin and mode of formation.

Soil Order: A grouping of soils on the basis of the character of the soil mass—as mineral or organic.

(A new term used only by the author.)

Physical Characteristics of Soils

Soil Texture: Texture is a term indicating the coarseness or fineness of the soil mass; the combined or mass effect of the different sizes and quantities of individual grains or particles making up the soil.

As the soil is usually made up of particles of widely varying size, the textural terms usually express the average effect or the combined effect of all these grain sizes, but they may indicate the predominance (in quantity or in textural effect) of a certain group of grains.

The textural composition is determined by mechanical analysis—a laboratory process of separating the soil into groups of grain-sizes. The system of mechanical analysis used by the Bureau of Soils of the United States Department of Agriculture separates the soil into seven grain-sizes or "separates" having the following size and name:

	mm.
Fine gravel	2. —1.
Coarse sand	1. —0.5
Sand	0.5 —0.25
Fine sand	0.25 —0.10
Very fine sand	0.10 —0.05
Silt	0.05 —0.005
Clay	0.005— ?

Sands contain less than 20 per cent of silt and clay.

Sandy Loams contain from 20 to 50 per cent of silt and clay but do not have over 20 per cent of clay.

Loams have more than 50 per cent of silt and clay combined but have less than 50 per cent of silt and less than 20 per cent of clay.

Silt Loams have more than 50 per cent of silt and less than 20 per cent of clay.

Clay Loams have more than 50 per cent of silt and clay combined but less than 50 per cent of silt and between 20 per cent and 30 per cent of clay.

Clays have more than 50 per cent of silt and clay combined and more than 30 per cent of clay.

Textural Grade: A classification of soils based on texture alone.

This has been called the "class" in many soil publications.

In the field texture is determined by the feel of the soil mass when rubbed between the fingers. The following statements give the obvious physical characteristics of the basic textural grades:

Sand: Sand is loose and single-grained. The individual grains can readily be seen or felt. Squeezed in the hand when dry it will fall apart when the pressure is released. Squeezed when moist, it will form a cast but will crumble when touched.

Sandy Loam: A sandy loam is a soil containing much sand but which has enough silt and clay to make it somewhat coherent. The individual sand grains can readily be seen and felt. Squeezed when dry, it will form a cast which will readily fall apart, but if squeezed when moist a cast can be formed that will bear careful handling without breaking.

Loam: A loam is a soil having a relatively even mixture of the different grades of sand and of silt and clay. It is mellow with a somewhat gritty feel, yet fairly smooth and slightly plastic. Squeezed when dry, it will form a cast that will bear careful handling, while the cast formed by squeezing the moist soil can be handled quite freely without breaking.

Silt Loam: A silt loam is a soil having a moderate amount of the fine grades of sand and only a small amount of clay, over half of the particles being of the size called "silt". When dry it may appear quite cloddy but the lumps can be readily broken, and when pulverized it feels soft and floury. When wet the soil readily runs together and puddles. Either dry or moist it will form casts that can be freely handled without breaking, but when moistened and squeezed between a thumb and finger it will not "ribbon" but will give a broken appearance.

Clay Loam: A clay loam is a fine textured soil which usually breaks into clods or lumps that are hard when dry. When the moist soil is pinched between the thumb and finger it will form a thin "ribbon" which will break readily, barely sustaining its own weight. The moist soil is plastic and will form a cast that will bear much handling. When kneaded in the hand it does not crumble readily but tends to work into a heavy compact mass.

Clay: A clay is a fine textured soil that usually forms very hard lumps or clods when dry and is quite plastic and usually sticky when wet. When the moist soil is pinched out between the thumb and fingers it will form a long, flexible "ribbon". Some fine clays very high in colloids are friable and lack plasticity in all conditions of moisture.

Gravelly or Stony Soils: All of the above grades of soil, if mixed with a considerable amount of sand, gravel or stone, are designated as sandy clay loams, sandy clays, etc., as gravelly sandy loams, gravelly clays, etc., or as stony sandy loams, stony loams, etc.

Soil Separate: One of the several grain-size groups into which the soil is separated by mechanical analysis.

Colloid—Colloidal: Particles of colloidal size (below 1_u diameter) present in sufficient amount to have an appreciable effect on the soil character.

Heavy (Textured): Applied to soils of fine texture in which clay predominates, with dense structure and firm to compact consistence.

The term is also applied to soils containing a somewhat higher proportion of the finer separates than is typical of that textural grade (as a "heavy sandy loam").

Light (Textured): Applied to soils of coarse to medium texture with very low silt and clay content, incoherent, single-grained structure, and loose consistence.

The term is also applied to soils containing somewhat higher proportions of the coarser separates than is typical of that textural grade (as a "light loam").

Sharp: Containing angular particles in sufficient amount to dominate the "Feel". Abrasive.

Gritty: Containing a sufficient amount of angular grains of coarse sand or fine gravel so that these dominate the "feel". Usually applied to medium textured soils (loams) where the actual quantity of these coarse grains is quite small.

Smooth: Containing well rounded coarser particles and a predominance of the finer separates. Not abrasive.

Velvety: Very smooth textured, free from any coarse particles, usually free from any except the smallest aggregates.

Floury: Fine-textured soil consisting predominantly of silt (or flocculated clay with aggregates of silt size) which when dry is incoherent, smooth and dust-like.

Porosity

Soil Porosity: Porosity is a term indicating the mass effect of the pores or voids between the individual particles and aggregates that make up the soil.

Porous: A soil having a maximum of voids or pore spaces.

Dense: A soil having a minimum of pore space and an absence of any large pores or cracks.

Structure

Soil Structure: Structure is a term expressing the arrangement of the individual grains and aggregates that make up the soil mass.

The structure may refer to the natural arrangement of the soil when in place and undisturbed or to the soil at any degree of disturbance. The terms used indicate the character of the arrangement, the general shape and the size of the aggregates and in some cases may indicate the consistence of these aggregates.

Crumb-Structure: Porous aggregates of irregular shape, rarely over 2 cm. in diameter and of a medium to soft consistence.

Fine Crumb—Crumbs 5 mm. or less in diameter.

Coarse Crumb—Crumbs 2 cm. or more in diameter.

Mealy: A crumb-like structure where the aggregates are of soft to very soft consistence and usually less than 5 mm. in diameter.

Granular: Aggregates varying in size to 2 cm. in diameter, of medium consistence, and more or less subangular or rounded in shape.

Fine Granular: Aggregates under 5 mm. diameter.

Coarse Granular: Aggregates close to maximum size.

Buckshot: Aggregates of roughly spherical shape, usually 2 or 3 mm. in diameter, and of a hard consistence.

Lump (Lumpy): Aggregates of irregular shape, of medium to hard consistence and from 2 to 10 cm. in diameter.

Clod (or Cloddy): Aggregates of irregular, angular shape, usually 8 cm. or more in diameter and of a hard consistence.

Fine Cloddy—When most of the clods are close to the minimum size (8 to 12 cm.).

Coarse Cloddy—When most of the clods are 20 cm. or more in diameter.

Adobe: A soil which on drying cracks and breaks into irregular but roughly cubical blocks. The cracks are usually wide and deep and the blocks are from 20 to 50 or more centimeters across. (Adobe soils are usually heavy-textured and high in content of colloidal clay.)

Structureless: Without any discernible structure or arrangement of the soil particles into aggregates.

Puddled: A condition of massive structure brought about when by artificial or natural action the previously existing structures are broken down and destroyed. Deflocculated.

Pulverulent: The soil reduced to a mass of soft crumbs and granules.

Fluffy: A surface condition where the aggregates are loose, of light weight and fine texture, with no cohesion or evidence of arrangement; floury.

Mulch (or Mulched): An horizon with a loose, incoherent arrangement of aggregates of mealy, crumb or granular structure.

Crust (or Crusted): Where the upper or surface horizon coheres into plate or crust distinct from the horizon immediately below it.

Tilth

Soil Tilth: Tilth is a term indicating the condition of soil structure brought about by manipulation; an artificial structure produced by tillage or cultivation.

Terms indicating the condition of tilth are the same as those indicating the soil structure under the broken or disturbed conditions, as mealy, pulverulent, granular, crumb, buckshot, mulch, nut-structure, cloddy.

Consistence

Soil Consistence: Consistence is a term expressing the degree of cohesion of the soil and the resistance opposed to forces tending to deform or rupture the aggregates.

Consistence and structure are closely related and frequently interdependent. The terms expressing consistence and structure are distinct, however, and need not be confused or used with double meaning.

Loose: A soil with particles or small aggregates that are independent of each other or are very weakly cohering, with a maximum of pore space and a minimum resistance to forces tending to cause rupture.

Soft: A soil that yields readily to any force causing rupture or deformation. Aggregates readily crushed between fingers.

Mellow: A soil with particles or aggregates that are weakly adhering in a rather porous mass, readily yielding to forces causing rupture. A consistence softer than friable. Without tendency to pack.

Friable: A soil with aggregates that can be readily ruptured and crushed with application of moderate force. Easily pulverized or reduced to crumb or granular structure.

Firm: A soil resistant to forces tending to produce rupture or deformation. Moderately hard. Aggregates can be broken between fingers.

Compact: A soil that is dense and firm, but without any cementation. Quite resistant to forces tending to cause rupture or deformation. Coherent.

Relative degree of compactness can be expressed by terms as slightly compact, very compact, etc.

Hard: A soil resistant to forces tending to cause rupture or deformation. Difficult or impossible to crush aggregates with fingers only.

Brittle: A soil which when dry will break with a sharp, clean fracture. If struck a sharp blow, it will shatter into cleanly broken hard fragments.

Plastic—Plasticity: A soil readily deformed without rupture. Pliable but cohesive. Can be readily moulded. Putty-like.

Cheesy: A soil having a more or less elastic character, deforming considerably without rupture, yet broken without difficulty or the application of much force.

Characteristic of certain highly colloidal soils when thoroughly wet.

Sticky: A soil that shows a decided tendency when wet to adhere to other materials and foreign objects.

Tenaceous: A soil that shows a decided resistance to rupture. The soil mass coheres firmly.

Sticky and Tenaceous are often used as synonyms, but in soil usage the former is taken to refer to adhesion, the latter to cohesion. Both may be present in a soil at the same time.

Stiff: A soil that is resistant to rupture or deformation. A soil stratum or horizon that is firm and tenaceous, and tending toward impervious.

Usually applied to condition of the soil in place and when moderately wet.

Tight: A term applied to strata or horizons of the soil that are compact, impervious and tenaceous and usually plastic.

Tough: A soil that is resistant to rupture. Tenaceous. A term applied to strata or horizons of the soil that can be readily bored into with the auger but which requires much force in breaking loose and pulling out the core of soil.

Impervious: A soil very resistant to penetration by water and usually to air and to plant roots. Impenetrable.

In field practice the term is applied to strata or horizons that are very slowly penetrated by water and that retard or restrict root penetration. Relatively Impervious or Slowly Pervious are better expressions.

Cemented—Cementation: A condition occurring when the soil grains or aggregates are caused to adhere firmly and are bound together by some material that acts as a cementing agent (as colloidal clay, iron, silica, or aluminum hydrates, lime carbonate, etc.).

Chemical Characteristics

Calcareous Soil: A soil containing sufficient calcium carbonate to effervesce when tested with weak 0.1 N hydrochloric acid.

In accordance with the amounts present, these soils may be designated as slightly calcareous, strongly calcareous, etc.

Acid Soil: A soil that is deficient in available bases, particularly calcium, and which gives an acid reaction when tested by standard methods.

There is no full agreement on the most satisfactory test for "acidity" and field tests are made by the use of various convenient indicators. The intensity or degree of acidity can be expressed by the qualifying words—strongly, moderately, etc.

Alkali Soil—Alkali: A soil containing any soluable salts in sufficient amount to cause injury to economic plants.

Alkaline Soil: A soil containing an excessive amount of the alkaline (in true chemical sense) salts, usually sodium carbonate.

Saline Soil: A soil containing excessive amounts of the neutral or non-alkaline salts, usually chlorides and sulphates.

In reprinting the glossary presented by Mr. Shaw, we have omitted many of the terms that we believed would be of little interest to 90 per cent of our *Record* readers.

Attention is called to the "Introduction," wherein the author states that most of the terms apply to soil in the field. For example, clays are listed with the group terms that are differentiated by their physical characteristics without reference to their chemical composition. Hence the term finds a wide and correct local usage in Hawaii, which would not be true if the definition were to be applied only to the true clays, the hydrated aluminum silicates, for these silicates are not found in Hawaiian soils.

In regard to the terms listed under "chemical characteristics," we feel that the local usage of "acid" and "alkaline" soils, with their various intensities as determined by the pH analyses, are desirable. Thus *for the agricultural soils* in Hawaii, we would justify the terms that follow:

Very acid	Below pH 5.2	Very alkaline.....	Above pH 8.8
Acid	pH 5.2—pH 5.7	Alkaline	pH 8.3—pH 8.8
Moderately acid.....	pH 5.8—pH 6.3	Moderately alkaline.	pH 7.7—pH 8.2
Slightly acid.....	pH 6.4—pH 6.7	Slightly alkaline....	pH 7.3—pH 7.6
	Neutral	pH 6.8—pH 7.2	

In the original paper, the author makes the following comment concerning his "chemical terms":

A few chemical terms in general use are included in the glossary. It is hoped that the term "Alkali Soil" can be eliminated and these soils more correctly designated as Alkaline or Saline soils, depending on the character of the compounds present. If it is felt necessary to have a general term to express the opposite of "Acid" soil, the term "Basic" soil might be better.

R. J. B.

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
DECEMBER 28, 1933, TO MARCH 15, 1934

Date	Per Pound	Per Ton	Remarks
Dec. 28, 1933	3.15¢	$63.00	Philippines.
" 29	3.175	63.50	Philippines, 3.15; Cubas, 3.20.
Jan. 2, 1934	3.20	64.00	Cubas.
" 11	3.165	63.30	Philippines, 3.16; Puerto Ricos, 3.17.
" 17	3.17	63.40	Puerto Ricos, Philippines.
" 19	3.20	64.00	Puerto Ricos.
" 26	3.23	64.60	Puerto Ricos.
" 27	3.24	64.80	Puerto Ricos, 3.23, 3.25.
" 31	3.25	65.00	Puerto Ricos.
Feb. 3	3.30	66.00	Puerto Ricos.
" 5	3.35	67.00	Puerto Ricos.
" 7	3.39	67.80	Puerto Ricos.
" 8	3.4733	69.47	Puerto Ricos, 3.40; Philippines, 3.42; Cubas, 3.60.
" 13	3.3767	67.53	Puerto Ricos, 3.35, 3.38, 3.40.
" 14	3.35	67.00	Puerto Ricos.
" 15	3.46	69.20	Cubas, 3.57; Puerto Ricos, 3.35.
" 16	3.45	69.00	Puerto Ricos, 3.35; Cubas, 3.55.
" 17	3.33	66.60	Puerto Ricos.
" 19	3.30	66.00	Puerto Ricos, Philippines.
" 20	3.27	65.40	Puerto Ricos.
" 21	3.29	65.80	Philippines.
" 26	3.385	67.70	Puerto Ricos, Philippines, 3.30; Cubas, 3.47.
" 27	3.30	66.00	Puerto Ricos.
" 28	3.31	66.20	Philippines, 3.30; Puerto Ricos, 3.32.
Mar. 1	3.32	66.40	Puerto Ricos, 3.34, 3.32; Philippines, 3.30.
" 2	3.30	66.00	Philippines.
" 5	3.26	65.20	Puerto Ricos, 3.27, 3.26, 3.25.
" 6	3.215	64.30	Puerto Ricos, 3.23, 3.20.
" 7	3.20	64.00	Puerto Ricos.
" 12	3.34	66.80	Cubas, 3.48; Puerto Ricos, 3.20.
" 13	3.17	63.40	Philippines, 3.19; Puerto Ricos, 3.15.
" 14	3.15	63.00	Puerto Ricos.
" 15	3.42	68.40	Cubas.